6. Analysis of Efficiency and Productivity Changes in Potato Farming: Stochastic Frontier Production Function Approach

6.1 Introduction

This chapter analyses efficiency and productivity changes of potato production in Mongolian agriculture in the period 1976-1989. Because the analytical parts, including model specification and estimational procedures, are the same as in the case of grain farms in Chapter 5, these sections have been omitted here. The chapter is organised as follows: Section 6.2 discusses the results of partial factor productivity (PFP) measures and indices of individual inputs in potato production; Section 6.3 reports the results of the stochastic frontier production function (SFPF) with time-varying inefficiency effects model for potato farms; and Section 6.4 summarises the results of the analysis and concludes the chapter.

6.2 Partial Factor Productivity Measures

The PFPs of individual inputs are reported in Table 6.1. In 1989, land productivity was 13 998 kgs/ha and labour productivity was 222 kgs/manday; fertiliser productivity was 56 kgs/tg and capital and other costs productivities were 7 kgs/tg and 20 kgs/tg respectively.

In terms of annual average growth rates of PFPs[1] (the last row of Table 6.1), calculated by regressing the logged indices upon a linear time trend (specified the same way as in Section 5.2) the highest growth rate was observed in land

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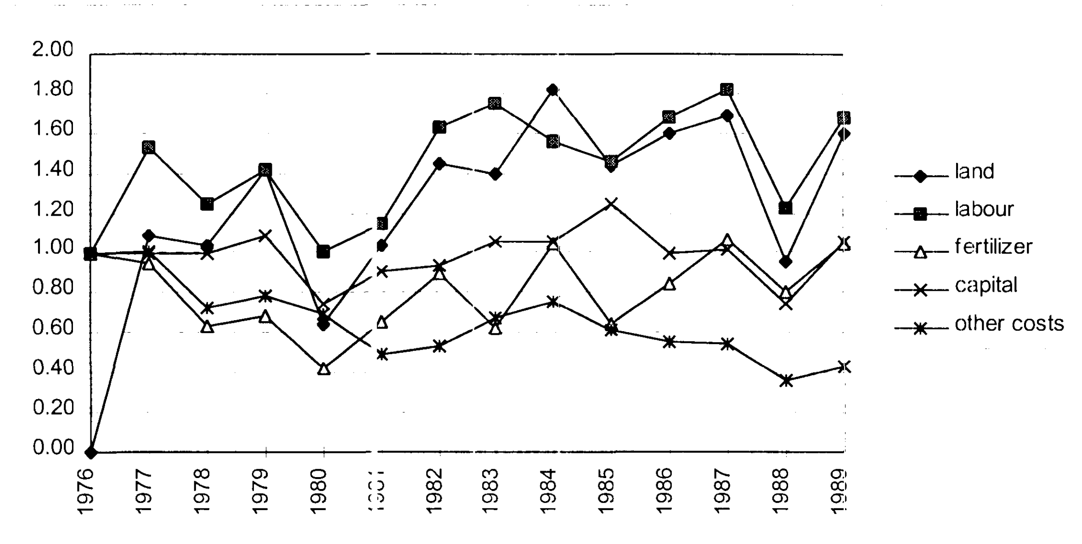
[1] The estimation results of the annual growth rates of PFPs for individual inputs are reported in Appendix 2, Tables A2.1 and A2.2. The results suggest that PFP growth rates for land, labour and other costs are significant at five percent level but those for capital and fertilizer are not significant due to large standard errors.

Table 6.1 Partial factor productivities of potato farms, 1976-1989

Year	Partial factor productivity of: Land (kgs/ha)	Labour (kgs/manday)	Fertiliser (kgs/tg)	Capital (kgs/tg)	Other costs (kgs/tg)
1976	8 746	132	54	7	46
1977	9 516	202	51	7	46
1978	9 074	164	34	7	33
1979	12 382	188	37	7	36
1980	5 633	133	23	5	32
1981	9 027	151	35	6	23
1982	12 667	215	48	6	24
1983	12 255	231	34	7	31
1984	15 882	205	56	7	35
1985	12 559	192	35	8	28
1986	13 980	222	45	7	26
1987	14 796	240	58	7	25
1988	8 370	162	43	5	17
1989	13 998	222	56	7	20
Annual growth rate (per cent)	3.43	2.58	1.78	0.04	-5.72

productivity (3.43 per annum) followed by labour productivity (2.58 per cent per annum) and fertiliser productivity (1.78 per cent per annum). Annual growth rate of capital productivity was near zero (0.04 per cent per annum) and that of other costs was negative (-5.72 per cent per annum). The trends of PFP indices of potato production over the study period are depicted in Figure 6.1 with year 1976 being selected as the base year. PFPs of all inputs fell until 1980, then the PFPs for land and labour increased moderately, and those of the rest of the inputs were either around the 1976 level (fertiliser and capital) or below the productivity levels of 1976 (other costs). It should be noted here that the first five years (1976-1980) of the study period, where all PFPs fell, was the policy period when the Ministry of Agriculture aimed to achieve output growth mainly by increased use of conventional inputs.

Figure 6.1 **Partial factor productivities of potato farms, 1976-1989**



6.3 Stochastic Frontier Production Function with Time-varying Inefficiency Effects Model

A two-stage procedure for specification of the functional forms and inefficiency-effects model similar to that given in Chapter 5 was used here.

6.3.1 Empirical results

The SFPF with time-varying inefficiency effects model was estimated for the three separate sub-periods 1976-1980, 1981-1985 and 1986-1989, each reflecting a different policy period.[2] As mentioned earlier, the final set of preferred models was identified through a two-stage procedure similar to the grain farm case in Chapter 5. In the first stage, a series of statistical tests was conducted to select the appropriate functional form. In the second stage, four different inefficiency-effects models were estimated from which the preferred models were identified for final reporting. The output elasticities with respect to individual inputs, the changes in technology, and the levels and changes in efficiency are reported for each of the three sub-periods.

6.3.1.1 Alternative functional forms

The output elasticities of the SFPF with time-varying inefficiency effects model for the potato farms under the alternative functional forms are reported below in Table 6.2.[3] Most of the partial output elasticities at the mean of the data were of the expected sign and magnitude except for fertiliser. The results of the time variable used as a proxy for technical change are as follows. In the first sub-period (1976-1980), negative technical change at the mean of the data was found to be the case for both translog and the Cobb-Douglas functions. In the second sub-period (1981-1985), positive technical change was found for both the translog and the Cobb-Douglas cases whereas in the third sub-period (1986-1989) negative technical change was indicated in both the translog and the Cobb-Douglas cases. Thus, in the case of potato farms, the alternative functional forms seemed to produce similar values for technical change in terms of both signs and magnitudes.

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[2] The models were also applied to the total period of 14-year data (1976-1989). However, the Chow-test result on separate vs. total period (to establish if structural change was observed) supported the division into the three different sub-periods against the total period. The parameter estimates and results of Chow-tests are reported in Appendix 2, Table A2.3.

[3] The full report of the parameter estimates of the models is given in Appendix 2, Tables A2.4-A2.6.

Table 6.2 Output elasticities of the SFPFs with time-varying inefficiency effects model for potato farms under alternative functional forms, 1976-1980; 1981-1985; 1986-1989[a]

Variable		Translog	Cobb-Douglas
1976-1980:			
Land	β_1	0.803	0.795
		(0.072)	(0.075)
Labour	β_2	0.180	0.170
		(0.058)	(0.057)
Fertiliser	β_3	0.068	0.008
		(0.047)	(0.043)
Capital	β_4	0.156	0.216
		(0.059)	(0.055)
Other costs	β_5	0.112	0.074
		(0.039)	(0.041)
Time	β_6	-0.107	-0.066
		(0.056)	(0.063)
1981-1985:			
Land	β_1	0.5958	0.6915
		(0.0901)	(0.0804)
Labour	β_2	0.280	0.251
		(0.061)	(0.059)
Fertiliser	β_3	-0.001	0.007
		(0.037)	(0.029)
Capital	β_4	0.238	0.179
		(0.057)	(0.042)
Other costs	β_5	0.033	0.032
		(0.029)	(0.029)
Time	β_6	0.010	0.022
		(0.054)	(0.047)
1986-1989:			
Land	β_1	0.635	0.636
		(0.086)	(0.075)
Labour	β_2	0.190	0.217
		(0.064)	(0.063)
Fertiliser	β_3	0.041	0.030
		(0.047)	(0.039)
Capital	β_4	0.178	0.174
		(0.072)	(0.065)
Other costs	β_5	0.072	0.0805878
		(0.033)	(0.0300047)
Time	β_6	-0.118	-0.091
		(0.054)	(0.066)

[a] **Estimated standard errors are presented below the corresponding parameter estimates**

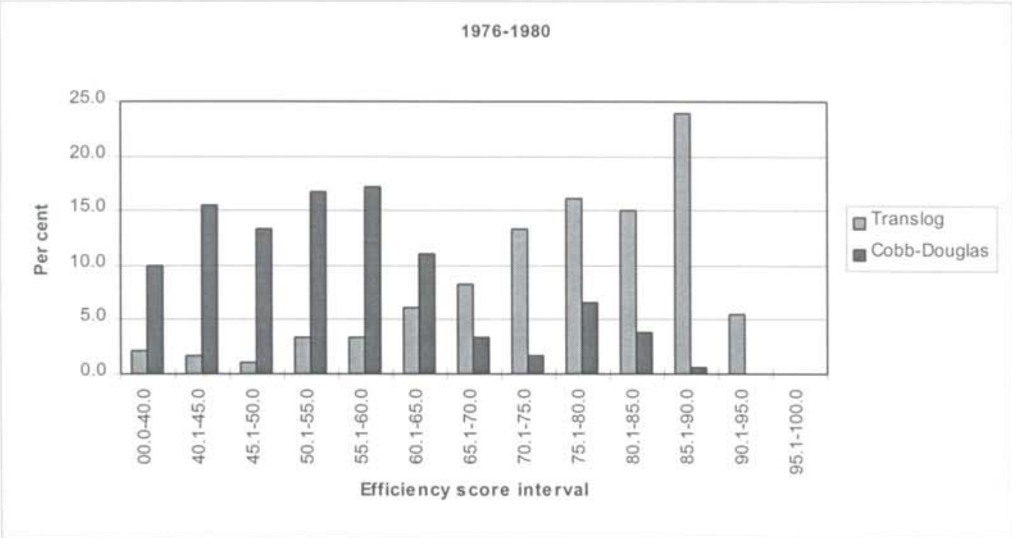
The mean efficiency scores under alternative functional forms are reported in Table 6.3. The differences in mean technical efficiencies among the alternative functional specifications were observed more clearly in the first sub-period and less so in the second and third sub-periods. In the first sub-period (1976-1980), the mean technical efficiency of potato farms was higher for the translog function (0. 758) than that of the Cobb-Douglas (0.543). In the second sub-period, the mean technical efficiency of the potato farms was almost identical under the translog (0.766) and the Cobb-Douglas (0.767) functional forms. In the third sub-period, however, the mean efficiency of the translog function (0.804) was again higher than that of the Cobb-Douglas (0.696). So, in most cases the translog – the more general functional form – appears to produce higher efficiency score than the Cobb-Douglas form. This may be explained by the fact that the more general functional form envelopes the data in a more flexible way than the less general functional form thus narrowing the gap between the frontier and the individual farms operating underneath it.

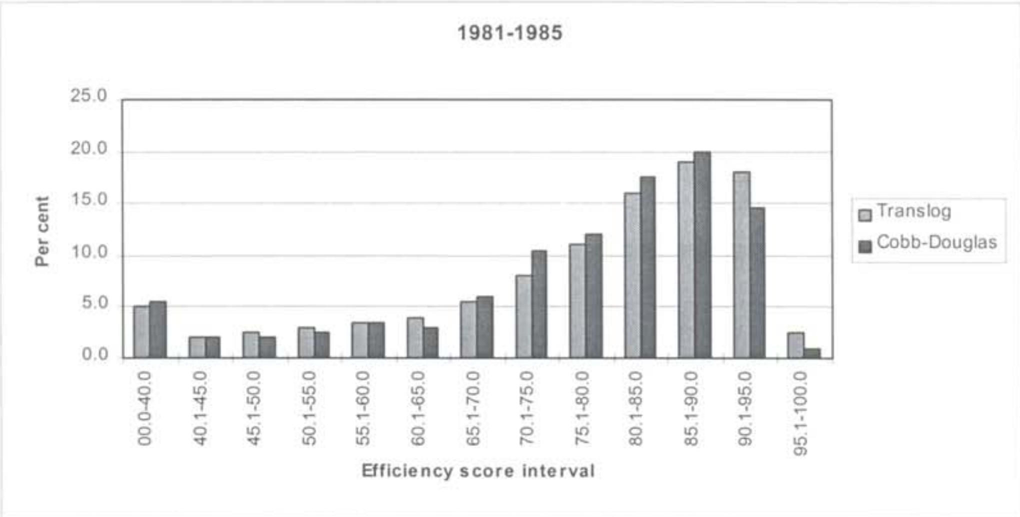
Table 6.3 Mean efficiency scores of potato farms under alternative functional forms, 1976-1980; 1981-1985; 1986-1989

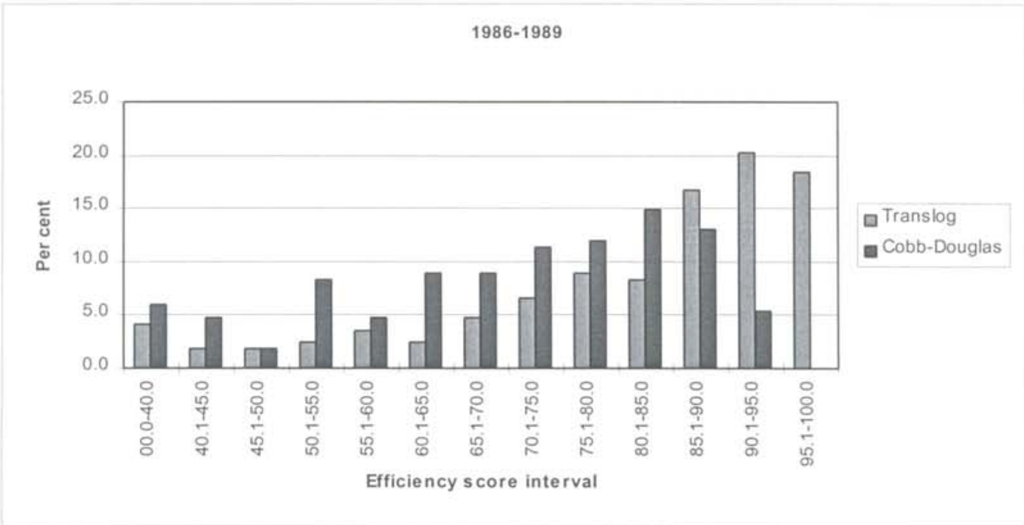
	Translog	Cobb-Douglas
1976-1980	0.758	0.543
1981-1985	0.766	0.761
1986-1989	0.804	0.696

As illustrated in Figure 6.2, the efficiency distributions of potato farms under the translog and Cobb-Douglas functional forms appear to follow differing patterns in the first sub-period, whereas in the second and third sub-periods both functional forms follow a similar pattern.

Figure 6.2 **Effects of alternative functional forms on efficiency scores of potato farms, 1976-1980; 1981-1985; 1986-1989**







In the first sub-period, the potato farms under the translog functional form produced a distributional form left-skewed but the Cobb-Douglas form produced distributional form right-skewed (as the functional form became more restricted, the efficiency distribution tended to shift more to the left implying lower efficiency level).

In the second and third sub-periods, potato farms under alternative functional forms produced left-skewed distributions. The results therefore suggest that the choice of functional form mildly affected the level and distribution of farm efficiencies in the first sub-period and had no effect in the second and third sub-periods. This latter result seems contrary to the findings for grain farms in Chapter 5, but conforms with the findings of Good *et al.* (1993) and Ahmad (1994, p. 94) who suggest that the scores of the efficiency measures do not depend on functional form.

A series of statistical tests was conducted for each of the time periods to select the most appropriate functional form for the next stage of the analysis. The results are reported in Table 6.4.

1) For the first sub-period (1976-1980), given the specification of the translog functional form, the null hypothesis that all second-order terms are not significantly different from zero was strongly rejected. Hence, the translog functional form was preferred to the Cobb-Douglas functional form. However, the null hypothesis that non-neutral technical change is absent was accepted.

2) For the second sub-period (1981-1985), given the specification of the translog functional form, the null hypothesis that all second-order terms are not significantly different from zero was accepted. Therefore, the Cobb-Douglas functional form was preferred against the translog function. Furthermore, the null hypothesis that neutral technical change is absent was accepted.

3) For the third sub-period (1986-1989), given the specification of the translog functional form, the null hypothesis that all second-order terms are not significantly different from zero was strongly rejected.

Table 6.4 Generalised likelihood-ratio tests of hypotheses for parameters of the SFPF models for potato farms, 1976-1980; 1981-1985; 1986-1989

Assumption	Null Hypothesis H_0	$Ln[L(H_0)]$	Value of λ statistic	Critical value	Decision
1976-1980					
1.0 Translog		-157.40			
1.1 Cobb-Douglas	H_0: $\beta_{ij}=\beta_{tj}=\beta_{tt}=0$, $i,j=1,\ldots,5$.	-182.72	50.66	32.67	Reject H_o
1.2 Translog (no technical change)	H_0: $\beta_{tj}=\beta_t=\beta_{tt}=0$ $j=1,\ldots,5$.	-162.93	11.06	14.07	Accept H_o
1981-1985					
2.0 Translog		-160.84			
2.1 Cobb-Douglas	H_0: $\beta_{ij}=\beta_{tj}=\beta_{tt}=0$, $i,j=1,\ldots,5$.	-171.10	20.51	32.67	Accept H_o
2.2 Cobb-Douglas (no technical change)	H_0: $\beta_t=0$	-171.24	0.28	3.84	Accept H_o
1986-1989					
3.0 Translog		-115.60			
3.1 Cobb-Douglas	H_0: $\beta_{ij}=\beta_{tj}=\beta_{tt}=0$, $i,j=1,\ldots,5$.	-133.62	36.03	32.67	Reject H_o
3.2 Translog (no technical change)	H_0: $\beta_{tj}=\beta_t=\beta_{tt}=0$ $j=1,\ldots,5$.	-121.11	11.02	14.07	Accept H_o

Therefore, the translog functional form was preferred to the Cobb-Douglas functional form. However, the null hypothesis that non-neutral technical change is absent was accepted. Thus the results suggest that in the third sub-period technical change was not present.

In summary, the results of the statistical tests suggest that in the first and third sub-periods the translog function was favoured against the more restrictive Cobb-Douglas functional form, whereas in the second sub-period the Cobb-Douglas functional form was favoured against the translog functional form. The technical change was absent in all sub-periods.

6.3.1.2 Alternative inefficiency-effects specifications

Based on the preferred functional specifications selected in the previous section, the following four different inefficiency-effects models were estimated:

Model (a): time-varying inefficiency-effects model (5.3-5.5) proposed by Battese and Coelli (1992)

Model (b):time-invariant inefficiency-effects model (Battese, Coelli and Colby, 1989) – the restriction $\eta = 0$ of (5.10) was imposed on the model of 5.3-5.5.

Model (c): inefficiency effects follow the half-normal distribution – the restriction $\mu = 0$ (5.11) was imposed on the model of 5.3-5.5.

Model (d): average production function – the restriction $\gamma = \mu = \eta = 0$ of (5.12) was imposed on the model of 5.3-5.5.

The output elasticities of individual inputs in the three sub-periods under alternative inefficiency-effects models are reported in Table 6.5 below. Except for fertiliser, all output elasticities were found to have the expected signs and magnitudes. In all cases, the partial output elasticity with respect to fertiliser was found to be statistically not significant. The signs of partial output elasticity with respect to fertiliser were positive except for the average function case in the second sub-period. The overall results suggest that the parameters of all the first-order terms across alternative inefficiency-effects models tend to have similar values and signs.

Also, as shown in Table 6.6, the mean efficiencies tend to have similar values under alternative inefficiency-effects models except for the time-varying inefficiency effects model (Model (a)) in the first sub-period.

As Figure 6.3 demonstrates, with the exception of the time-invariant inefficiency-effects model (Model (b)), in most cases alternative inefficiency-effects models have a similar distributional pattern for efficiency scores. While in all three sub-periods potato farms show a fairly even distribution across all ranges of efficiency intervals, in the second sub-period, the time-invariant inefficiency-effects model (Model (b)) produced a distributional pattern where over 40 per cent of farms operated in the efficiency range of 0.801-0.850. Another noticeable difference can be observed in the same model (Model (b)) in the third sub-period. Here, the efficiency distribution was more towards the left than were the other two model specifications in this sub-period.

The overall result of this analysis is the indication of little difference in parameter estimates, efficiency levels and their distributions among the alternative specifications of the inefficiency-effects model.

The results of the statistical tests for identifying the most appropriate inefficiency specifications of the stochastic frontier for potato farms are reported in Table 6.7. For the first sub-period (1976-1980), the null hypothesis that η (the trend parameter for the inefficiency effects) is not significantly different from zero was rejected.

Table 6.5 Output elasticities of the SFPFs for potato farms under alternative inefficiency-effects models[a], 1976-1980; 1981-1985; 1986-1989

Variable		Model (a)[b]	Model (b)[b]	Model (c)[b]	Model (d)[b]
1976-1980:					
Land	β_1	0.789	0.760	0.792	0.771
		0.069)	(0.075)	0.069	(0.077)
Labour	β_2	0.176	0.216	0.184	0.233
		0.059)	(0.062)	0.058	(0.063)
Fertiliser	β_3	0.061	0.031	0.053	0.011
		0.049)	(0.049)	0.049	(0.052)
Capital	β_4	0.172	0.173	0.177	0.158
		0.059)	(0.061)	0.059	(0.067)
Other costs	β_5	0.121	0.111	0.109	0.117
		0.042)	(0.042)	0.041	(0.046)
1981-1985:					
Land	β_1	0.693	0.756	0.694	0.762
		0.081)	(0.078)	(0.081)	(0.082)
Labour	β_2	0.253	0.254	0.255	0.279
		0.060)	(0.063)	(0.060)	(0.062)
Fertiliser	β_3	0.009	0.017	0.006	0.002
		0.033)	(0.035)	(0.033)	(0.036)
Capital	β_4	0.176	0.148	0.177	0.149
		0.042)	(0.043)	(0.042)	(0.047)
Other costs	β_5	0.032	0.034	0.033	0.037
		0.028)	(0.031)	(0.029)	(0.032)
1986-1989:					
Land	β_1	0.622	0.623	0.621	0.648
		0.085)	(0.091)	(0.085)	0.093
Labour	β_2	0.194	0.167	0.191	0.172
		0.065)	(0.068)	(0.066)	0.067
Fertiliser	β_3	0.069	0.040	0.069	0.020
		0.042)	(0.043)	(0.042)	0.046
Capital	β_4	0.154	0.203	0.157	0.201
		0.074)	(0.073)	(0.073)	0.079
Other costs	β_5	0.084	0.084	0.083	0.081
		0.029)	(0.031)	(0.029)	0.032

a Estimated standard errors are presented below the corresponding parameter estimates.

b Model (a): Time-varying inefficiency effects model.
Model (b): Time-invariant inefficiency effects model.
Model (c): Half-normal distribution is assumed for the inefficiency term.
Model (d): Average production function where no inefficiency is assumed.

Table 6.6 Mean efficiency scores of potato farms under alternative inefficiency-effects models[a], 1976-1980; 1981-1985; 1986-1989

	Model (a)	Model (b)	Model (c)
1976-1980	0.583	0.757	0.727
1981-1985	0.758	0.769	0.725
1986-1989	0.766	0.722	0.752

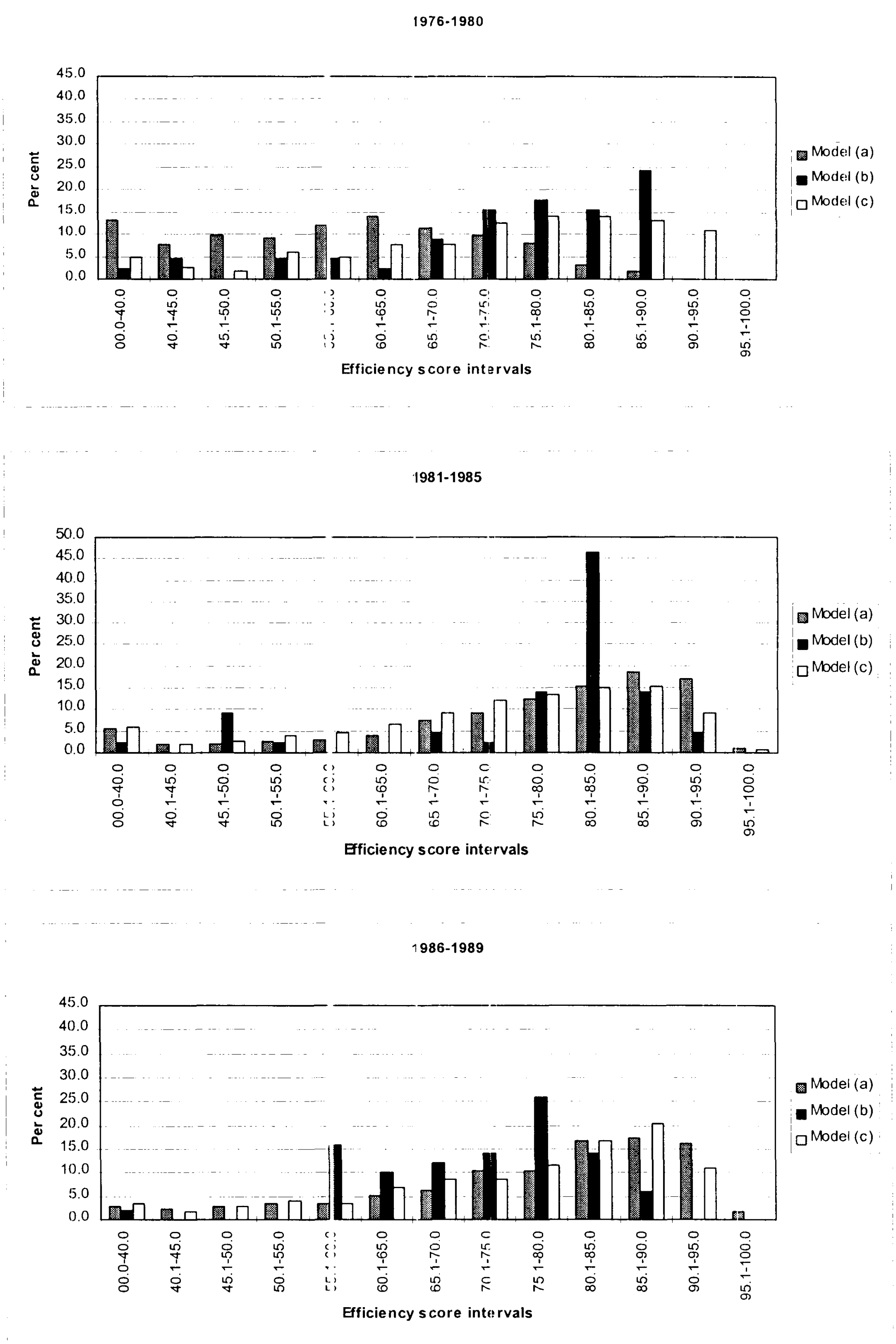
[a] In Model (d), because of average function was assumed, no efficiency scores were calculated.

Model (a): Time-varying inefficiency effects model.
Model (b): Inefficiency trend is not present.
Model (c): Half-normal distribution is assumed for the inefficiency term.

Next, the null hypothesis that the half-normal distribution for the inefficiency term ($\mu = 0$) was preferred to a more general representation was accepted. Last, the null hypothesis that $\gamma = \eta = \mu = 0$ is rejected, implying that the traditional average response function in which farms are fully efficient is not an adequate representation of the data. Hence, the SFPF is preferred to an average production function.

For the second sub-period (1981-1985), the null hypothesis that η (the trend parameter for the inefficiency) is not significantly different from zero was rejected. But the null hypothesis that the half-normal distribution for the inefficiency term ($\mu = 0$) was preferred to a more general representation was accepted. The null hypothesis that $\gamma = \eta = \mu = 0$ was rejected, implying that the traditional average response function in which farms are fully efficient is not an adequate representation of the data. It suggests that the SFPF is preferred to an average response function in describing the production technology.

Figure 6.3 Effects of alternative inefficiency-effects models on efficiency scores of potato farms[a], 1976-1980; 1981-1985; 1986-1989



[a] Model (a): Time-varying inefficiency effects model.
Model (b): Inefficiency trend is not present.
Model (c): Half-normal distribution is assumed for the inefficiency term.

For the third sub-period (986-1989), the null hypothesis that η (the trend parameter for the inefficiency) is not significantly different from zero was rejected. However, the null hypothesis that the half-normal distribution for the inefficiency term ($\mu = 0$) was preferred to a more general representation was accepted. The null hypothesis that $\gamma = \eta = \mu = 0$ was rejected. So, the SFPF is preferred to an average response function.

In summary, the two consecutive statistical tests conducted above suggested the following specifications for the final preferred model in individual sub-periods:

First sub-period (1976-1980) Time-varying inefficiency effects model with a half-normal distribution for he inefficiency term (and the translog function with no technical change).

Second sub-period (1981-1985): Time-varying inefficiency effects model with a half-normal distribution for the inefficiency term (and the Cobb-Douglas with no technical change).

Third sub-period (1986-1989): Time-varying inefficiency effects model with a half-normal distribution for he inefficiency term (and the translog function with no technical change).

In other words, the results of the statistical tests in all three sub-periods suggest that the SFPFs with inefficiency effects were favoured over the traditional average response function representation. This implies that the inefficiency was consistently present throughout the whole study period. Furthermore, the inefficiency trend increased in the first sub-period (1976-80), but decreased in the subsequent two sub-periods (1981-1985 and 1986-89). In all sub-periods, the half-normal distributional form was favoured. The final estimates of the preferred models are detailed in the next section.

Table 6.7 Generalised likelihood-ratio tests of hypotheses for variance parameters of the SFPF models for potato farms, 1976-1980; 1981-1985; 1986-1989

Assumption	Null Hypothesis H_0	$Ln[L(H_O)]$	Value of λ statistic	Critical value	Decision
1976-1980					
Unrestricted model[a]		-162.93			
Inefficiency trend is not present	H_0: $\eta = 0$	-171.20	16.54	3.84	Reject H_o
Half-normal distribution for the inefficiency term is adequate	H_0: $\mu = 0$	-163.59	1.32	2.71[b]	Accept H_o
Inefficiency is not present	H_0: $\gamma = \eta = \mu = 0$	-173.87	21.88	7.05[b]	Reject H_o
1981-1985					
Unrestricted model[a]		-171.23			
Inefficiency trend is not present	H_0: $\eta = 0$	-181.68	20.90	3.84	Reject H_o
Half-normal distribution for the inefficiency term is adequate	H_0: $\mu = 0$	-171.73	1.00	2.71[b]	Accept H_o
Inefficiency is not present	H_0: $\gamma = \eta = \mu = 0$	-189.02	35.58	7.05[b]	Reject H_o
1986-1989					
Unrestricted model[a]		-121.11			
Inefficiency trend is not present	H_0: $\eta = 0$	-125.49	8.76	3.84	Reject H_o
Half-normal distribution for the inefficiency term is adequate	H_0: $\mu = 0$	-121.15	0.08	2.71[b]	Accept H_o
Inefficiency is not present	H_0: $\gamma = \eta = \mu = 0$	-127.20	12.18	7.05[b]	Reject H_o

[a] The unrestricted models are the models which have been selected from the first-stage statistical tests as described earlier.

[b] If $\gamma = 0$ is included in the H_O, then λ has a mixed chi-square distribution (see Coelli, 1996a). The critical value for λ in this case is obtained from Kodde and Palm (1986).

6.3.1.3 Parameter estimates

The parameter estimates of the preferred SFPF with inefficiency effects model in the three sub-periods are reported in Table 6.8 below. With the exception of fertiliser, all first-order terms of individual inputs interpreted as partial elasticities were found to be positive and significant at the five per cent level. Although the signs of the partial output elasticity with respect to fertiliser were positive, they were not significant due to high standard errors.

The partial output elasticity with respect to land was found to be largest among the inputs, ranging between 0.621 and 0.79, though its value decreased over time (0.79, 0.694 and 0.621 in the first, second and third sub-periods respectively). The partial output elasticity with respect to labour was found to be the second largest. Its value varied between 0.184 and 0.255. Compared with the first sub-period (0.184), its value increased in the second sub-period (0.255) then decreased in the third sub-period (0.191). The partial output elasticity with respect to capital was the third largest. Its value varied between 0.157 and 0.177. Its value remained the same in the first and second sub-periods (0.177) and slightly decreased in the third sub-period (0.157). The partial output elasticity with respect to other costs was found to be lowest among the significant first-order terms. In the first sub-period the partial output elasticity with respect to other costs was 0.109. In the second sub-period it declined to 0.063 and in the third sub-period recovered slightly with a value of 0.083. Again as in the case of grain farms, the relatively high estimates of output elasticities for traditional inputs land, labour and capital appear to support the relevance of the policy of increasing output by way of increased use of labour force, further expansion of land and investment of capital by the Ministry of Agriculture. Technical change was absent in all sub-periods.

Table 6.8 Maximum-likelihood estimates for the parameters of the SFPFs with time-varying inefficiency effects models for potato farms, preferred models[a], 1976-1980; 1981-1985 1986-1989

Variables		1976-1980	1981-1985	1986-1989
Constant	β_0	0.37	0.374	0.32
		(0.14)	(0.074)	(0.13)
Land	β_1	0.79	0.694	0.621
		(0.69)	(0.081)	(0.085)
Labour	β_2	0.184	0.255	0.191
		(0.058)	(0.060)	(0.066)
Fertiliser	β_3	0.053	0.006	0.069
		(0.049)	(0.033)	(0.042)
Capital	β_4	0.177	0.177	0.157
		(0.059)	(0.042)	(0.073)
Other costs	β_5	0.109	0.033	0.083
		(0.041)	(0.029)	(0.029)
$(Land)^2$	β_7	-0.063	-	0.093
		(0.059)	-	(0.104)
$(Labour)^2$	β_8	0.056	-	-0.024
		(0.036)	-	(0.042)
$(Fert.)^2$	β_9	0.028	-	-0.007
		(0.027)	-	(0.034)
$(Capital)^2$	β_{10}	0.063	-	-0.016
		(0.031)	-	(0.066)
$(Other\ costs)^2$	β_{11}	0.042	-	-0.009
		(0.023)	-	(0.017)
(Land x Labour)	β_{13}	0.265	-	0.003
		(0.077)	-	(0.091)
(Land x Fert.)	β_{14}	-0.091	-	-0.005
		(0.065)	-	(0.076)
(Land x Capital)	β_{15}	-0.096	-	-0.17
		(0.074)	-	(0.13)
(Land x Other costs)	β_{16}	0.046	-	-0.044
		(0.067)	-	(0.059)
(Labour x Fert.)	β_{18}	-0.017	-	0.069
		(0.046)	-	(0.039)
(Labour x Capital)	β_{19}	-0.250	-	-0.007
		(0.064)	-	(0.082)
(Labour x Other costs)	β_{20}	-0.057	-	-0.04274
		(0.042)	-	(0.04004)
(Fert. x Capital)	β_{22}	0.096	-	0.064
		(0.051)	-	(0.059)

(Fert. x Other costs)	β_{23}	-0.011	-	-0.033
		(0.032)	-	(0.028)
(Capital x Other costs)	β_{25}	-0.056	-	0.121
		(0.044)	-	(0.051)
$\sigma^2_S = \sigma^2_V + \sigma^2$		0.90	0.321	0.253
		(0.24)	(0.046)	(0.047)
$\gamma = \sigma^2/\sigma^2_S$		0.662	0.170	0.21
		(0.102)	(0.103)	(0.15)
μ		-	-	-
		-	-	-
η		-0.34	0.316	0.32
		(0.12)	(0.085)	(0.13)

[a] Estimated standard errors are presented below the corresponding parameter estimates.

As Table 6.9 suggests, increasing returns to scale[4] were found in all three sub-periods though with a slightly decreasing trend over time (1.32, 1.17 and 1.12 in the first, second and third sub-periods respectively). These returns-to-scale figures are slightly higher than those found in grain farms.

Table 6.9 Returns to scale of potato farms, 1976-1980; 1981-1985; 1986-1989

Period	Returns to scale $\beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5$
1976-1980	1.32
1981-1985	1.17
1986-1989	1.12

[4] Here, the returns to scale at the means of the data were defined as the sum of the first-order terms except for the time variable.

6.3.1.4 Efficiency scores and changes

A summary of the estimated technical efficiencies of the potato farms in individual sub-periods is presented in Table 6.10.[5] The mean efficiency scores of potato farms were 0.734, 0.723 0.752 in the first, second and third sub-periods respectively. These scores are lower than the mean efficiency scores of grain farms reported in Chapter 5.[6]

The signs and magnitudes of the trend variable for inefficiency term, η (Table 6.8), of the final preferred models suggest the following: The negative and significant value of η in the first sub-period implies that the inefficiency levels of potato farms increased during this period. However, positive and significant values of η in the second and third sub-periods suggest that the inefficiency levels of potato farms decreased during these periods.

As Table 6.10 shows, potato farm efficiency decreased in the first sub-period from 0.863 (1976) to 0.583 (1980), then increased in the second sub-period from 0.587 (1981) to 0.841 (1985) and also increased in the third sub-period from 0.658 (1986) to 0.834 (1989). These results are shown diagrammatically in Figure 6.4 below. The efficiency trend established here is as expected. Farm efficiencies decreased in the first sub-period, which is known as the "extensive growth" period, whereas they increased in the second and third sub-periods. These second and third sub-periods are matched with a "intensive" growth policy period when a significant importance was attached to farm restructuring, greater autonomy for farms and the introduction of improved incentive systems as a source of further output increase.

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[5] The full report of efficiency scores of the individual potato farms is given in Appendix 2, Tables A2.7-A2.9

[6] The reasons for this lower efficiency in potato farms are not readily apparent and this needs a further investigation.

Table 6.10 Summary of technical efficiency scores of potato farms, 1976-1980; 1981-1985; 1986-1989

1976-1980		1981-1985		1986-1989	
Year	Efficiency score	Year	Efficiency score	Year	Efficiency score
1976	0.863	1981	0.587	1986	0.658
1977	0.810	1982	0.660	1987	0.727
1978	0.743	1983	0.732	1988	0.788
1979	0.674	1984	0.791	1989	0.834
1980	0.583	1985	0.841		
mean	0.734		0.723		0.752
std. d	0.187		0.166		0.142
max	0.863		0.841		0.834
min	0.583		0.587		0.658

It is especially reassuring to note that the efficiency levels of both grain (Section 5.3.3.4) and potato farms decreased in the first sub-period, but increased in the third sub-period. This indicates that the shift from the so called "extensive" growth policy to an "intensive" growth policy brought about tangible improvements in farm performance.

In order to check the robustness of the efficiency trends established in the time-varying inefficiency effects model employed here, an alternative SFPF model originally proposed by Aigner, Lovell and Schmidt (1977) was estimated using the same data set. This specification assumes that all u_{it}s are uncorrelated with each other. Hence, in this model, the panel nature of the data is ignored and thus the efficiencies are free to choose their own temporal pattern. The results are compared with those of the panel data models proposed by Battese and Coelli (1992).

The efficiency results of this unrestricted model are plotted in Figure 6.5 below.[7] In the first sub-period, farm efficiency consistently declined except for the third year where a sudden upward jump was observed. In the second sub-period, efficiency of potato farms increased throughout the whole period. In the third sub-period, farm efficiency increased in the second year followed by a slight decline in the third year. Then it again picked up in the fourth year. Thus, the efficiency trend established in this model (Aigner *et al.* 1977) appears to support the efficiency trend of the time-varying inefficiency effects model (Battese and Coelli, 1992) implying that the results of the latter model are robust.

The efficiency distribution of potato farms in individual sub-periods is illustrated in Figure 6.6. The distributions of farms in all sub-periods have a similar shape and they appeared to have been distributed relatively evenly.

A closer look at the efficiency distribution from Table 6.11 reveals that the percentage of farms performing below 85 per cent of efficiency levels were 76.1, 75.0 and 68.5 in the first, second and third sub-periods respectively. During the overall period 1976-1989, about three quarters of all potato farms operated below 85 per cent efficiency. This suggests that there was considerable room for efficiency improvement in potato production. However, a gradual decline in the above percentage over time may indicate a corresponding improvement in the efficiency of potato farms as established in the time-varying inefficiency effects model.

The effect of farm size on farm efficiency was investigated. Sown area and capital were selected as criteria according to which farm efficiencies were ranked.[8] Efficiency ranking of farms by sown area (Table 6.12) suggests that in most cases large farms were most efficient followed by small farms. Medium-sized farms

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[7] The parameter estimates and the mean efficiency scores are reported in Appendix 2, Tables A2.10 and A2.11.

[8] The classification of farms into small, medium and large sizes was done in the same way as for grain farms in Chapter 5.

were found to be least efficient. For instance, large farms were found as the most efficient in the second and third sub-periods (0.794 and 0.786) and second most efficient in the first sub-period (0.734). Small farms were found as most efficient in the first sub-period (0.757) and second most efficient in the second and third sub-periods (0.699 and 0.751), whereas medium farms were ranked as least efficient in all three sub-periods (0.687, 0.678 and 0.717 in the first, second and third sub-periods respectively).

Figure 6.4 Efficiency trend of potato farms, 1976-1989

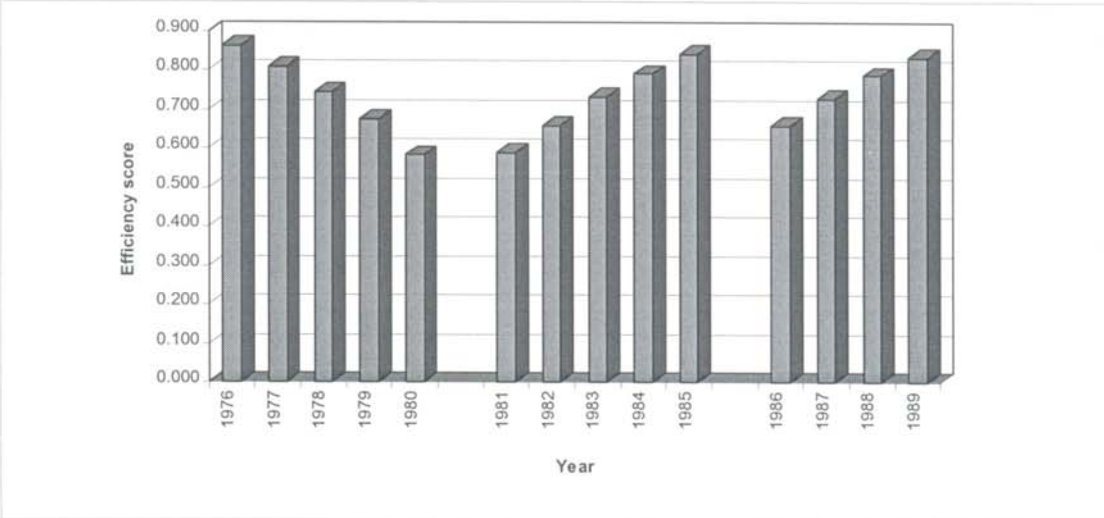

Figure 6.5 Efficiency trend of potato farms using Aigner *et al.* (1977) model, translog, 1976-1989

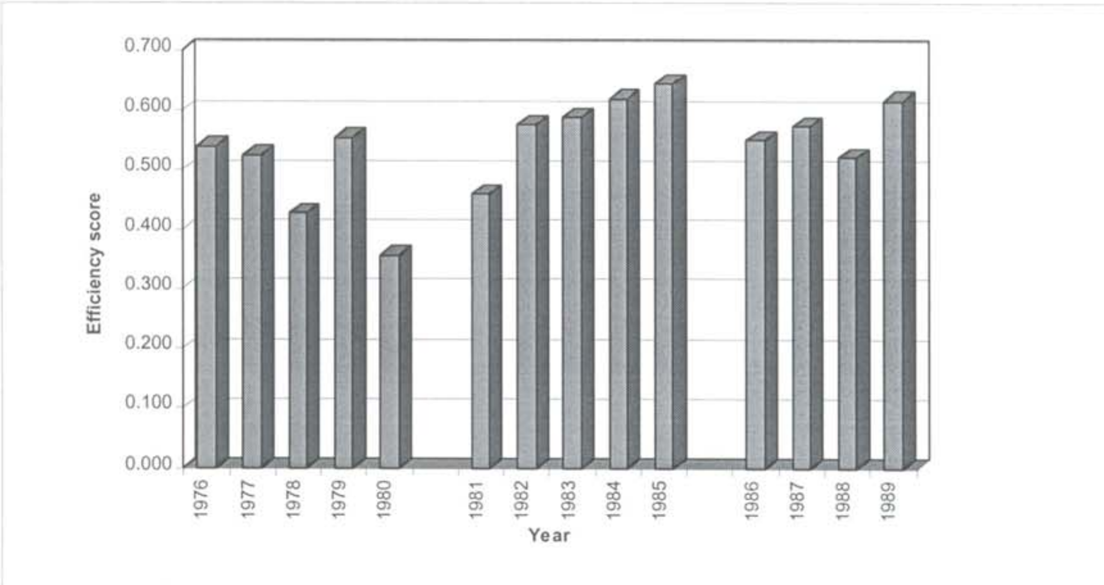

Figure 6.6 **Distribution of efficiency scores of potato farms, 1976-1980; 1981-1985; 1986-1989**

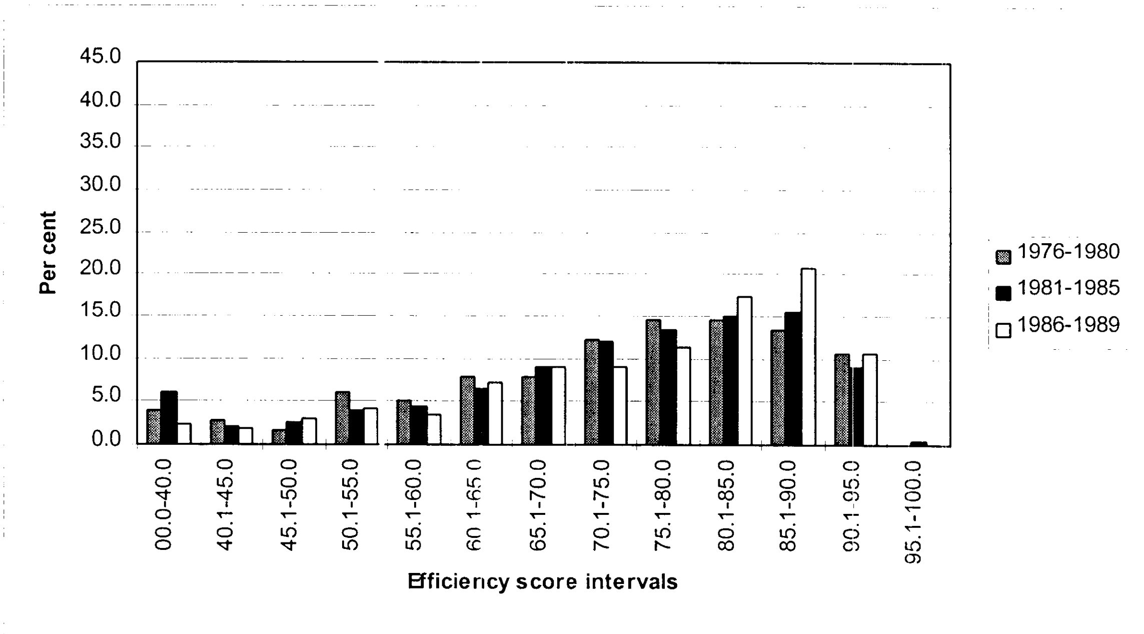

Table 6.11 Distribution of efficiency scores of potato farms, 1976-1980; 1981-1985; 1986-1989

Interval	Period		
	1976-1980	1981-1985	1986-1989
00.0-40.0	3.9	6.0	2.4
40.1-45.0	2.8	2.0	1.8
45.1-50.0	1.7	2.5	3.0
50.1-55.0	6.1	4.0	4.2
55.1-60.0	5.0	4.5	3.6
60.1-65.0	7.8	6.5	7.1
65.1-70.0	7.8	9.0	8.9
70.1-75.0	12.2	12.0	8.9
75.1-80.0	14.4	13.5	11.3
80.1-85.0	14.4	15.0	17.3
85.1-90.0	13.3	15.5	20.8
90.1-95.0	10.6	9.0	10.7
95.1-100.0	0.0	0.5	0.0
Total	100.0	100.0	100.0

Table 6.12 Efficiency scores ranked by size of farm measured as sown area; potato farms, 1976-1980; 1981-1985; 1986-1989

Period	Farm size (according to sown area)		
	Small	Medium	Large
1976-1980	0.757	0.687	0.734
1981-1985	0.699	0.678	0.794
1986-1989	0.751	0.717	0.786

The above results suggest that during the period 1976-1989 large farms generally performed at higher efficiency levels than the small or medium farms.

Efficiency scores ranked according to farm capital (Table 6.13) suggest that large farms achieved the highest efficiency scores in the second and third sub-periods (0.781 and 0.788) and second most efficient in the first sub-period (0.718). Small farms were ranked as most efficient in the first (0.756), second most efficient in the third (0.736) and least efficient in the second sub-period (0.676). Medium farms were ranked second most efficient in the second sub-period (0.716) and least efficient in the first and third sub-periods (0.707 and 0.730).

Table 6.13 Efficiency scores of potato farms ranked by capital; potato farms, 1976-1980; 1981-1985; 1986-1989

Period	Farm size (according to capital in tgs)		
	Small	Medium	Large
1976-1980	0.756	0.707	0.718
1981-1985	0.676	0.716	0.781
1986-1989	0.736	0.730	0.788

To sum up, when farm sizes were measured either by sown area or by capital, large farms were consistently found as most efficient (in four out of six cases). Small farms appear to have performed second most efficiently and medium farms performed least efficiently.

Next, in order to investigate the effects of natural conditions on farm performance, the efficiency scores of individual farms were ranked by agro-ecological region.

The results of efficiency ranking of potato farms according to agro-ecological region (Table 6.14) suggest that farms in the most fertile region (Selenge-Onon) were the most efficient in the second sub-period (0.757) and the third sub-period (0.768) and were the second most efficient in the first sub-period (0.720).

Farms in the second most fertile region (Hangai-Huvsgul), were ranked as the second most efficient in the second (0.706) and third (0.734) sub-periods and the most efficient in the first sub period (0.771).

Table 6.14 Efficiency scores of potato farms ranked by agro-ecological region, 1976-1980; 1981-1985; 1986-1989

Period	Agro-ecological region: Selenge-Onon	Hangai-Huvsgul	Central and Eastern steppe
1976-1980	0.720	0.771	0.697
1981-1985	0.757	0.706	0.493
1986-1989	0.768	0.734	0.689

Farms located in the least-fertile region (the Central and Eastern Steppe) were ranked as least efficient in all three sub-periods (0.697, 0.493 and 0.689 in the first, second and third sub-periods respectively). These results suggest a fairly consistent picture in efficiency ranking among the agro-ecological regions: the more fertile the agro-ecological region, the more efficient were the farms. The only exception was observed in the first sub-period, where the farms in the second-most fertile agro-ecological region were found to be most efficient.

6.3.1.5 TFP changes

The information on changes in mean technical efficiency (from year to year) and estimates of technical change (evaluated at the sample means in each year) were used to obtain indices of TFP change between each pair of adjacent years over the 14-year sample period for potato farms. These measures are summarised by the cumulative indices listed in Table 6.15 and plotted in Figure 6.7.[9]

It was observed that over the 14-year period there was a 3.4 per cent decline in technical efficiency but a 15.5 per cent increase in technical change, resulting in an overall increase in TFP of 11 6 per cent.

The trend pattern of TFP suggests that while in the first sub-period TFP declined due to declining efficiency and stagnant technical change, in the second sub-periods TFP increased due to increases both in efficiency and technical change. In the third sub-period TFP increased due to improvements in efficiency which was moderated by some decline in technical change. Overall, in the final nine years of the study period (1980-1989), TFP increased by 65.1 per cent.

Significant technical progress occurred only at the beginning of the second sub-period, which roughly coincides with substantial investments in new technology and seeds made by the Ministry of Agriculture. These initiatives of the Ministry of Agriculture perhaps somehow helped increase farm productivity during that period.

During the nine years 1980-1989, efficiency consistently increased until 1989 (except for a decline in 1985/1986) resulting in a 42.8 per cent increase in efficiency during this period. This trend is similar to the grain case and may suggest that incentive reform policies of the 1980s had some positive impacts on farm performance.

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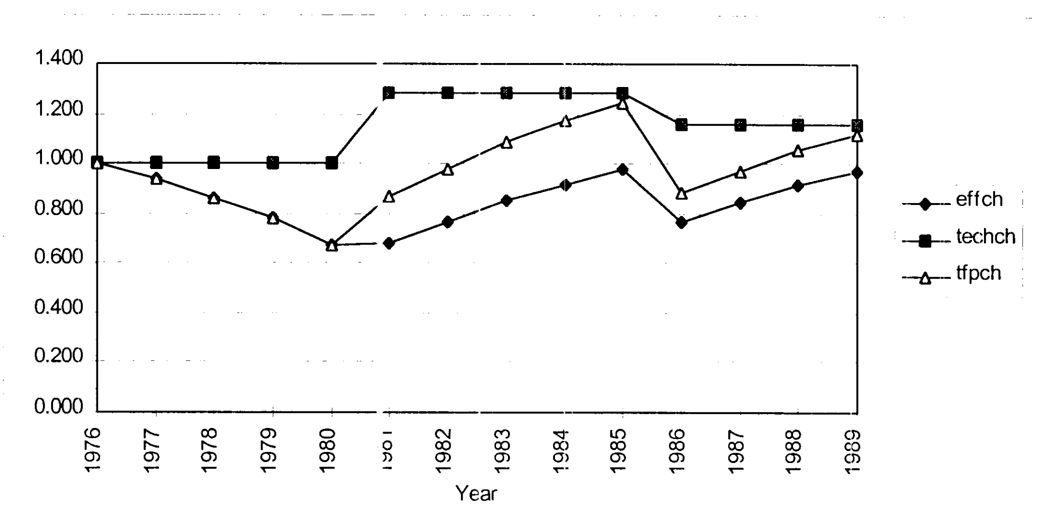
[9] The technical change measures for the junctions of the two different sub-periods were calculated in the same way as in the case of grain. The output file of the Shazam program for the calculation is given in Appendix 4.

Table 6.15 Cumulative index of changes in efficiency, technology and TFP of potato farms, 1976-1989

Year	Efficiency change	Technical change	TFP change
1976	1.000	1.000	1.000
1977	0.938	1.000	0.938
1978	0.862	1.000	0.862
1979	0.781	1.000	0.781
1980	0.676	1.000	0.676
1981	0.681	1.279	0.871
1982	0.765	1.279	0.979
1983	0.849	1.279	1.086
1984	0.917	1.279	1.173
1985	0.975	1.279	1.247
1986	0.763	1.155	0.881
1987	0.842	1.155	0.972
1988	0.913	1.155	1.054
1989	0.966	1.155	1.116
Total change (per cent)	-3.4	15.5	11.6

Figure 6.7 **Cumulative index of changes in efficiency, technology and TFP of potato farms, 1976-1989**[a]



[a] effch - Efficiency change.
techch - Technical change.
tfpch - TFP change.

6.4 Summary and Conclusions

Production technology, efficiency and TFP in Mongolian potato farms for the period 1976-1989 were investigated using both PFP measures and the SFPF framework.

The PFPs of individual inputs for potato farms over the 14-year period showed differing trends, thus failing to give an unambiguous picture of the overall productivity change of the farms. For instance, the PFPs for land and labour for the period 1976-1989 increased moderately, but those for fertiliser, capital and other costs were either remained around the 1976 level or below it. A large year-to-year fluctuation in PFPs of individual inputs was also observed.

A SFPF for potato farms was estimated for each of the three sub-periods, 1976-1980, 1981-1985 and 1986-1989 each representing an important policy period.

A two-stage specification procedure similar to that of Kumbhakar and Hjalmarsson (1993c) was used for identification of production technology and the inefficiency-effects models. In the first stage, an adequate production technology, including the type of technical change, was identified through various modifications of the translog function. In the second stage, the specification of the inefficiency term was determined and the final preferred models were estimated.

The specification results suggested that the translog was preferred to the Cobb-Douglas functional form for the first and third sub-periods and the Cobb-Douglas was preferred against the translog for the second sub-period. In all sub-periods except for the years[10] 1980/1981 and 1985/1986 technical change was seemingly absent. In all three sub-periods, it was strongly suggested that inefficiency was present and that a half-normal distribution for the inefficiency-effects terms was preferred over a truncated normal distribution. Statistically significant inefficiency trends were established in all three sub-periods. Inefficiency increased in the first sub-period but decreased in the second and third sub-periods. The results also suggested that the selection of functional forms and the specification of inefficiency terms affected the efficiency scores of individual farms. However, the selection of functional forms appeared to have more effect on the level and the distribution of farm efficiency than did the latter. This implied that a proper specification of production technology was necessary to obtain more realistic results.

The estimation results of the preferred model suggested the following:

At the means of the data, the partial output elasticities with respect to land was found to be largest (ranging between 0.621 and 0.790) followed by labour (ranging between 0.184 and 0.255) (Table 6.8). Consistently high values of these traditional inputs in all three sub-periods may suggest that the Government policy of output growth by way of increased use of traditional inputs in potato farms was justified. The relatively low partial output elasticities found for the modern inputs of capital (ranging between 0.157 and 0.177) and fertiliser (ranging between 0.006 and

[10] While in the year 1980/1981, a significant technical progress was observed, in the year 1985/1986 some technical regress was observed.

0.069) may partly suggest the failure of the Ministry of Agriculture to properly utilise these inputs. The absence or decline of technical change in all sub-periods (except for the year 1980/1981) perhaps suggested that the impact of Ministry of Agriculture policy of introducing new technology on the productivity of potato farms was disappointing.

Increasing returns to scale were found in all three sub-periods (1.32, 1.17 and 1.12 in the first, second and third sub-periods respectively) despite these values decreasing over time (Table 6.9).

Potato farms over the period 1976-1989 operated significantly under their potential (Table 6.10). They operated at average efficiency levels of 0.734, 0.723 and 0.752 in the first, second and third sub-periods respectively – lower than the mean efficiencies found in the case of grain farms (Table 5.10). However, the initial increase in farm inefficiency in the first sub-period was replaced by a significant decrease in farm inefficiency in the later periods (Table 6.10 and Figure 6.4). This may suggest that the Ministry of Agriculture efforts of the 1980s, including that of "Perestroika", to improve farm efficiency via successive reforms, resulted in some efficiency improvement. Efficiency scores of individual potato farms ranked according to sown area and capital consistently suggested in all three sub-periods that large farms were operating at higher efficiency levels than small and medium farms.

TFP increased by 11.6 per cent over the 14-year period mostly due to 27.9 per cent technical progress that occurred in the junction between the first and second sub-periods (1980/1981). In contrast, a total of 3.4 per cent of efficiency decline was observed over the 14-year period.

A closer look at the changing pattern over time suggests that a total of 65.1 per cent increase in TFP was observed for the period 1980-1989. This was due to both technical progress (15.5 per cent) and efficiency improvements (a 42.8 per cent). This substantial improvement in efficiency coincided with the economic reform in the sector that took place in the 1980s, possibly suggesting that these reforms had a positive impact on farm performance.

7. Analysis of Efficiency and Productivity Changes in Grain and Potato Farming: Data Envelopment Analysis Approach

7.1 Introduction

This chapter applies data envelopment analysis (DEA), a non-parametric linear programming technique, to the measurement of efficiency and total factor productivity (TFP) changes in Mongolian grain and potato farms for the period 1976-1989 and compares the results with those of the SFPF models presented in Chapters 5 and 6. The chapter is organised as follows: Section 7.2 discusses the basic output-orientated DEA models for efficiency measurement and their extensions accommodating various scale effects. These DEA models are then applied to the farm-level production data for both grain and potato farms. The results of the efficiency analysis are reported. Section 7.3 discusses the construction of the Malmquist index of TFP changes and the distance-function concepts upon which the former is built. Malmquist TFP indices are constructed for both grain and potato farms for the period 1976-1989 using DEA methods. Section 7.4 compares these DEA-based results with the SFPF results from Chapters 5 and 6. Section 7.5 summarises and concludes the chapter.

7.2 Measurement of Efficiency

In the previous two chapters (Chapters 5 and 6), an efficiency and productivity analysis of Mongolian grain and potato farms was conducted using a parametric approach: the SFPF framework. Despite some methodological advantages, the SFPF also has some shortcomings. These shortcomings, in the context of the current study are: the imposition of an arbitrary functional form on the production technology without prior knowledge, and a priori assumptions on the distribution of efficiency terms. The DEA method, which is a non-parametric approach based on mathematical programming methods, can effectively avoid these shortcomings and produce efficiency scores free of any biases which could possibly have stemmed from the assumptions stated above in the SFPF context. Therefore, it was considered that by applying the DEA models to the same input and output data sets of grain and potato farms as used in the SFPF case, the robustness of the SFPF models could be tested.

The input-orientated DEA models were discussed extensively in Chapter 2. However, in this study, because the output-target system was used in Mongolian crop farming (which can be described at best as output maximising system), the output-orientated DEA models were considered as more appropriate and selected accordingly in the current analysis.

The graphical representation of output-orientated efficiency measurement for the CRS two-output case (Y_1, Y_2), is presented in Figure 7.1. A production possibility frontier, *FABG*, for two outputs (Y_1, Y_2) can be constructed in the DEA context.

While firms *A* and *B* are efficient as they are located on the frontier, firms *C*, *D* and *E* are inefficient, because they are below the frontier. Using Farrell's radial and equi-proportionate measure of efficiency, these points can be projected to the points C', D' and E' and the distances CC', DD' and EE' are attributed as efficiency shortfalls. The problem of slack arises here: while the firm *D* has reached the efficiency point in Koopmans' (1951) sense, the firms *C* and *E* reached the efficiency points only in Farrell's (1957) sense.[1] In the DEA approach, using a mathematical programming technique, a deterministic frontier is constructed over the entire set of observations and then Farrell radial-efficiency measures of each firm are calculated against this frontier.

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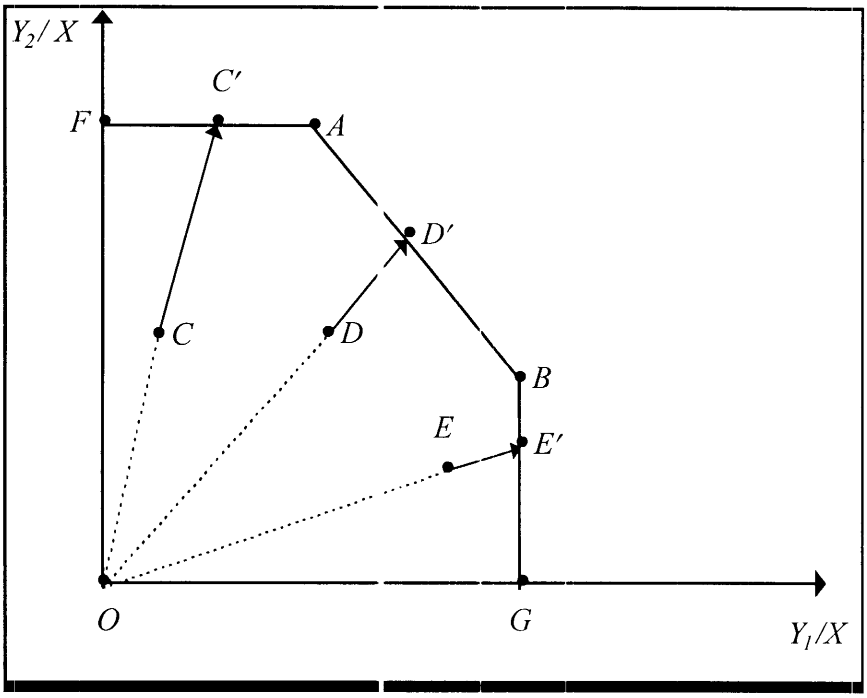
[1] Discussion of Koopmans' vs. Farrell's efficiency was presented in Chapter 2.

Figure 7.1 Output-orientated efficiency measurement in DEA context



Let us assume there are N firms to be evaluated, each having K inputs and M outputs. The i-th firm utilises input vector, x_i to produce output vector, y_i. The K x N input matrix, X, and the M x N output matrix, Y, represent the data of all N firms.

Following Färe, Grosskopf, Norris and Zhang (1994), the linear programming problem for calculating Farrell efficiency measures for the i-th firm is formulated as:

(7.1) $max_{\phi,\lambda}\ \phi$

subject to:

(7.2) $-\phi y_i + Y\lambda \geq 0$

(7.3) $x_i - X\lambda \geq 0$

(7.4) $\lambda \geq 0$

where x_i and y_i are the input and output vectors of the *i*-th firm, the efficiency of which is being measured. The ϕ is the scalar which gives the efficiency measure of the *i*-th firm by the solution of the model and λ is the vector of constants.

The constraint (7.2) implies that the reference (frontier) firm should produce at least as much as firm *i* and the constraint (7.3) implies that the input use of firm *i*, after being adjusted by efficiency coefficients, should be at least as much as the input use of the reference firm. Also, ϕ is the efficiency measure signifying by how much the output vector can be extended, given the conditions stated in the restrictions (7.2) - (7.4).

The above formulation gives the efficiency measures of the individual firms assuming a constant returns-to-scale (CRS) technology.

To calculate variable returns-to-scale (VRS) efficiency measures, the following convexity constraint needs to be added to the above restrictions:

(7.5) $N1'\lambda = 1;$

where $N1$ is $N \times 1$ vector of ones.

To calculate the non-increasing returns-to-scale (NIRS) efficiency measures, the restriction

(7.6) $N1'\lambda \leq 1$

should replace the restriction (7.5).

Once the efficiency scores of individual firms are calculated under the two different technologies, i.e., CRS and VRS, the scale efficiencies of individual firms can be calculated. The scale efficiency (*SE*) of a firm *i*, is defined as the ratio of technical efficiency scores under CRS and VRS technologies (Färe, Grosskopf and Lovell, 1994). That is:

(7.7) $SE_i = TE_{i,crs}/TE_{i,vrs}$

where $TE_{i,crs}$ is the technical efficiency score of firm *i* calculated under the CRS technology and $TE_{i,vrs}$ is the technical efficiency score of firm *i* calculated under the VRS technology.

Although the DEA model, as such, does not give any information about scale elasticities of production, by running a third DEA model under NIRS technology for the same data set and then by comparing the efficiency scores under all three technologies (CRS, VRS and NIRS), one can identify the scale regions at which individual firms are operating (Färe *et al.*, 1985). For instance, if the efficiency score of a VRS DEA model is equal to that of a NIRS DEA model, this implies that decreasing returns to scale is present. But if the efficiency score of a VRS DEA model is not equal to that of a NIRS DEA model, then an increasing returns to scale is present. Furthermore, if the efficiency scores under CRS and VRS technology are equal, then constant returns to scale is applicable.

These different specifications of DEA models were estimated using the DEAP Version 2.1 computer program written by Coelli (1996b).

7.2.1 Empirical results

The DEA frontiers have been constructed for individual years against which the efficiency scores of each grain and potato farms have been calculated. The efficiency scores of individual firms have been calculated for three different technologies, i.e., CRS, VRS and NIRS. While the efficiency scores under CRS technology represent the overall technical efficiency, the efficiency scores under VRS represent the pure technical efficiency scores (Färe *et al.*, 1985). Then the ratio between efficiency scores under CRS and VRS yields scale efficiency scores (as defined above). Table 7.1 displays the summary results of the overall technical, pure technical and scale efficiencies of grain and potato farms in the three policy sub-periods.

Table 7.1 Summary of technical, pure technical and scale efficiencies for grain and potato farms from DEA results, 1976-1980; 1981-1985; 1986-1989

Efficiency measure	1976-1980	1981-1985	1986-1989
Grain farms:			
Technical	0.750	0.737	0.808
Pure technical	0.804	0.815	0.852
Scale	0.933	0.902	0.947
Potato farms:			
Technical	0.678	0.706	0.694
Pure technical	0.797	0.803	0.783
Scale	0.851	0.879	0.885

In the case of grain, the overall technical efficiency scores were 0.750, 0.737 and 0.808 for the first, second and third sub-periods, respectively. Further break-down of the overall technical efficiency into pure technical and scale efficiency shows that the scale efficiency scores were higher than the pure technical efficiency scores.

In the case of potato, the average overall technical efficiency scores were 0.678, 0.706 and 0.694 in the first, second and third sub-periods. Again scale efficiency scores were to be found higher than pure technical efficiency scores. It therefore seems likely that, in both cases of grain and potato farms, improvements in overall technical efficiencies would be brought about by increasing pure technical rather than scale efficiencies.

Next, using the procedures described in the previous section, some information on the returns to scale of individual farms was also obtained. The percentage of farms that were operating under the three different scale ranges is reported in Table 7.2.

Table 7.2 Returns-to-scale classification of grain and potato farms from DEA results, 1976-1980; 1981-1985; 1986-1989

Scale effect	976-1980 (per cent)	1981-1985 (per cent)	1986-1989 (per cent)
Grain farms:			
DRS	36.1	41.6	30.7
CRS	29.0	25.4	22.9
IRS	34.9	33.0	46.4
Potato farms:			
DRS	14.4	14.5	24.4
CRS	33.9	36.0	36.3
IRS	51.7	49.5	39.3

As Table 7.2 suggests, the percentage of grain farms operating under decreasing returns to scale (DRS) increased in the second sub-period and then fell in the third sub-period. In the third sub-period, the farms which were operating under DRS constituted 31 per cent of all grain farms. The percentage of grain farms that were operating under CRS continuously declined over time and in the third sub-period 23 per cent of all grain farms were operating under CRS. But the percentage of grain farms operating under IRS substantially increased in the third sub-period after a slight decline in the second sub-period. As a result, in the third sub-period the percentage of farms falling in the category of IRS was 46 per cent.

In the potato farm case, the percentage of farms with DRS (14, 15 and 24 per cent in the first, second and third sub-periods, respectively) and CRS (34, 36 and 36 per cent in the first, second and third sub-periods, respectively) increased over time, while the percentage of farms with IRS (52, 50 and 39 per cent in the first, second and third sub-periods respectively) decreased although its share is highest among the three scale groups.

The overall percentage of potato farms operating under either CRS or IRS was very high (even higher than in the grain farm case) with a slight decline over time (86, 85 and 76 per cent in the first, second and third sub-periods respectively).

To summarise, throughout the 14-year period, the majority of grain and potato farms were operating under either CRS or IRS regions. About one-third of grain farms and less of potato farms were operating in the region of decreasing returns-to-scale (DRS).

7.3 Measurement of TFP Change

In the previous section, the Farrell radial technical efficiency scores of grain and potato farms were estimated using DEA methods. In the panel-data context, when farms are observed cross-sectionally as well as over time, the TFP change of individual farms can be calculated using DEA-like methods and the Malmquist index. The Malmquist index measures the TFP changes of individual firms and decomposes them into efficiency change and technical change.[2] Here, the efficiency change is measured as the change in distance of individual firms to the frontier from one year to another, whereas the technical change is measured as the (geometric) mean of the distances between the two frontiers. The construction of the Malmquist index and its connection to Farrell efficiency measures in the context of this analysis are discussed below.

Distance functions are the building blocks of the Malmquist index. They are more general representations of production technology than a production function because they can describe the production technology in a multiple-output, multiple-input setting.

The following exposition of the methodology, and the notation used, are based on Färe, Grosskopf, Norris and Zhang (1994) and Grosskopf (1993).

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[2] A graphical description and a some discussion of the Malmquist index of TFP change was given in Chapter 2.

Let us depict a production technology in period t by S_t which consumes $x_t \in R^N_+$ and produces $y_t \in R^M_+$. Here, x_t is a vector of inputs in N dimensional Euclidean positive space (R^N_+) and y_t is a vector of outputs in M dimensional Euclidean positive space (R^M_+). In set theory notation:

(7.8) $S_t = \{(x_t, y_t): x_t \text{ can produce } y_t\}$

where S_t is assumed to satisfy regular axioms (Färe, 1988).

The output distance function in period t (Färe, 1988) can be written as:

(7.9) $D^t_o(x_t, y_t) \quad = \inf\{\theta:(x_t, y_t/\theta) \in S_t\}$

where the subscript and superscript of D^t_o denote the output distance function and time period t respectively. The distance function (7.9) measures the maximal proportional change in the output vector y_t in order to make (x_t, y_t) possible for the technology S_t.

The distance functions mode the observations in period t the following way:

$D^t_o(x_t, y_t) \leq 1$ if and only if $(x_t, y_t) \in S_t$

and

$D^t_o(x_t, y_t) = 1$ if and only if (x_t, y_t) are the frontier points of the technology.

Similarly, the distance function in period $t+1$ using S_{t+1} technology can be written as:

(7.10) $D_o^{t+1}(x_{t+1}, y_{t+1}) = \inf\{\theta:(x_{t+1}, y_{t+1}/\theta) \in S_{t+1}$

For constructing the Malmquist productivity index, two additional distance functions utilising the information from both time periods, t and $t+1$ are needed:

(7.11) $D^t_o(x_{t+1}, y_{t+1}) = \inf\{\theta:(x_{t+1}, y_{t+1} / \theta) \in S_t\}$

and

(7.12) $D^{t+1}{}_{o}(x_t, y_t) = \inf\{\theta:(x_t, y_t / \theta) \in S_{t+1}\}$.

The distance function (7.11) measures the maximal proportional change in the output vector y_{t+1} in order to make (x_{t+1}, y_{t+1}) possible for the technology S_t. Similarly, the distance function (7.12) measures the maximal proportional change in the output vector y_t in order to make (x_t, y_t) possible for the technology S_{t+1}.

The initial Malmquist productivity index defined by Caves, Christensen and Diewert (1982a), which is usually denoted as $M^t{}_{CCD}$, is:

$$(7.13) \qquad M^{t}_{CCD} = \frac{D^{t}_{o}(x_{t+1}, y_{t+1})}{D^{t}_{o}(x_t, y_t)}$$

for base period t technology and

$$(7.14) \qquad M^{t+1}_{CCD} = \frac{D^{t+1}_{o}(x_{t+1}, y_{t+1})}{D^{t+1}_{o}(x_t, y_t)}$$

for base period $t+1$ technology.

Färe *et al.* (1989) defined the changes in output productivity as the geometric mean of two CCD-type output productivity indices, between periods t and $t+1$:

$$(7.15) \qquad M_o(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\left(\frac{D^{t}_{o}(x_{t+1}, y_{t+1})}{D^{t}_{o}(x_t, y_t))}\right)\left(\frac{D^{t+1}_{o}(x_{t+1}, y_{t+1})}{D^{t+1}_{o}(x_t, y_t)}\right)\right]^{\frac{1}{2}}$$

Following Färe *et al.* (1989) the above expression can also be written as the two separate components of the changes in efficiency and technology:

$$(7.16) \; M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D^{t}_{o}(x_{t+1}, y_{t+1})}{D^{t}_{o}(x_t, y_t)} \times \left[\left(\frac{D^{t}_{o}(x_{t+1}, y_{t+1})}{D^{t}_{o}(x_t, y_t)}\right)\left(\frac{D^{t+1}_{o}(x_{t+1}, y_{t+1})}{D^{t+1}_{o}(x_t, y_t)}\right)\right]^{\frac{1}{2}}$$

The first part of the expression, $\frac{D^{t+1}_{o}(x_{t+1}, y_{t+1})}{D^{t}_{o}(x_t, y_t)}$, reflects the change in efficiency from t to $t+1$, and the second part of the expression,

$\left[\left(\frac{D_o^t(x_{t+1}, y_{t+1})}{D_o^t(x_t, y_t)}\right) \times \left(\frac{D_o^{t+1}(x_{t+1}, y_{t+1})}{D_o^{t+1}(x_t, y_t)}\right)\right]^{1/2}$, expresses the technical change or shift in technology from t to $t+1$.

The Malmquist index of TFP change can have values greater than one (in the case of overall productivity improvement) or less than one (in the case of overall productivity deterioration). It is also possible that while the efficiency component is greater than one, the technical change is less than one. This could result in unchanged productivities. Such a possible outcome itself is useful additional information and may have different policy implications. For instance, while changes in the efficiency component are considered as a catching-up process, changes in technology may give information about the impacts of new research investment/innovation on production.

The actual estimation of the distance functions as component elements of the Malmquist index of TFP change is conducted using the fact that the distance functions are the reciprocals of the Farrell radial-efficiency measures. As discussed in the earlier sections of this chapter, the Farrell efficiency measures may be calculated using DEA methods. For one firm in two periods, t and $t+1$, the following four different linear programming problems for the CRS case are formulated to calculate the distance functions required in the Malmquist index of TFP change:

(7.17) $[d_o^t(x_t, y_t)]^{-1} = \max_{\phi,\lambda} \phi$

subject to:

$-\phi y_{it} + Y_t\lambda \geq 0$

$x_{it} - X_t\lambda \geq 0$

$\lambda \geq 0;$

(7.18) $[d_o^{t+1}(x_{t+1},y_{t+1})]^{-1} = max_{\phi,\lambda}\ \phi$

subject to:

$-\phi y_{it+1} + Y_{t+1}\lambda \geq 0$

$x_{it+1} - X_{t+1}\lambda \geq 0$

$\lambda \geq 0;$

(7.19) $[d_o^{t+1}(x_t,y_t)]^{-1} = max_{\phi,\lambda}\ \phi$

subject to:

$-\phi y_{it} + Y_{t+1}\lambda \geq 0$

$x_{it} - X_{t+1}\lambda \geq 0$

$\lambda \geq 0;$

(7.20) $[d_o^{t}(x_{t+1},y_{t+1})]^{-1} = max_{\phi,\lambda}\ \phi$

subject to:

$-\phi y_{it+1} + Y_t\lambda \geq 0$

$x_{it+1} - X_t\lambda \geq 0$

$\lambda \geq 0.$

Färe, Grosskopf, Norris and Zhang (1994) also proposed the enhanced Malmquist productivity index, where the efficiency-change component is further decomposed into pure technical efficiency and scale efficiency components by formulating the following two additional linear-programming problems for the CRS case:

(7.21) $[d_o^{t}(x_t,y_t)]^{-1} = max_{\phi,\lambda}\ \phi$

subject to:

$$-\phi y_{it} + Y_t\lambda \geq 0$$

$$x_{it} - X_t\lambda \geq 0$$

$$N1'\lambda = 1$$

and

(7.22) $$[d_o^{t+1}(x_{t+1}, y_{t+1})]^{-1} = max_{\phi,\lambda}\ \phi$$

subject to:

$$-\phi y_{it+1} + Y_{t+1}\lambda \geq 0$$

$$x_{it+1} - X_{t+1}\lambda \geq 0$$

$$N1'\lambda = 1.$$

It should be noted that the formulation of the above two linear programming problems is identical to the formulations in (7.17) and (7.18) except for the $N1'\lambda = 1$ restriction, which provides the VRS production technology in (7.21) and (7.22). Although it is possible to calculate the Malmquist index of TFP change relative to a VRS technology, this current study uses CRS for two main reasons. First, under a VRS technology, solutions may not exist in all inter-period linear programming problems (Färe, Grosskopf, Norris and Zhang 1994, p. 73). Second, the use of a VRS technology may result in TFP growth due to scale improvements being ignored (Färe *et al.*, 1995).

Alternative ways of estimating the distance functions' components have been proposed. For instance, under certain conditions, the Malmquist index can be calculated as a quotient of Törnqvist indices[3] (Caves *et al.*, 1982b) or as a quotient

[3] This requires the assumption that the production technology is of translog functional form where all second-order terms of the function are identical over time and economic efficiency holds for all firms.

of Fisher ideal indices[4] (Balk 1993). But it should be noted that both the Tornqvist and Fisher ideal indices need price or input-share data and also implicitly assume technical efficiency.

7.3.1 Empirical results

In this section the TFP changes for both grain and potato farms over the 14-year period 1976-1989 have been calculated using the Färe, Grosskopf, Norris and Zhang (1994) approach discussed above.

The summary of annual rates of TFP changes decomposed into technical change and efficiency change for grain and potato farms is reported in Table 7.3.

Table 7.3 Average annual change in Malmquist index of TFP change of grain and potato farms decomposed with scale effects, 1976-1989 (percentage)

Farm type	TFP change	Technical change	Efficiency change	of which changes in:	
				Pure tech. efficiency	Scale efficiency
Grain	-2.2	-2.1	-0.1	-0.4	0.3
Potato	0.5	-2.2	2.8	0.6	2.2

Here, also the efficiency change was further decomposed into pure technical efficiency change and scale efficiency change. In the case of grain farms, during the period 1976-1989, a 2.2 per cent decline in TFP per annum was observed. This was almost solely due to declines in technical change. A small decline in efficiency change (0.1 per cent per annum) was also observed. The decomposition

[4] This requires the assumption that economic efficiency holds for all firms.

of efficiency change into its elements reveals that pure technical efficiency change contributed negatively (-0.4 per cent per annum) whereas scale efficiency change contributed positively (0.3 per cent per annum). On the other hand, in the case of potato farms, a slight increase of half a per cent of TFP per annum was observed over the same period. However, the decomposition of TFP change into its elements reveals that technical change and efficiency change had the opposite effects: a decline of technical change of slightly over two per cent was observed along with close to a three per cent efficiency increase per annum. This overall efficiency increase was mostly due to improvements in scale efficiency (2.2 per cent) and less so to improvements in pure technical efficiency (0.6 per cent).

The cumulative Malmquist-based index of TFP change decomposed into efficiency change and technical change for grain and potato farms is reported in Table 7.4.

In the case of grain farms, over the period 1976-1989 almost a 25 per cent decline in TFP was observed. This was due to a 24 per cent decline in technical change and less than one per cent decline in efficiency. In the case of potato farms, the same index suggests that over the study period a 6.5 per cent increase in TFP occurred. The factors contributing to this change in TFP were contrasting: almost 25 per cent decline in technical change was accompanied by over 42 per cent increase in efficiency.

Figure 7.2 illustrates the trends of individual components of the Malmquist index of TFP change for grain and potato farms for the overall period of 14 years. In the case of grain farms (Figure 7.2(a)), the overall declining pattern of TFP can be observed despite extensive year-to-year fluctuations perhaps caused by random effects.[5] A closer look into its change pattern by three different policy sub-periods[6]

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[5] It should be noted that an attempt was made to eliminate random effects from the DEA results by adjusting the output level by weather fluctuations using OLS techniques on existing weather data. But the regression of outputs against the monthly temperature and precipitation did not yield satisfactory results, giving instead unexpected signs and magnitudes for the parameters of the variables. This was perhaps due to the fact that the available weather data collected by

Table 7.4 Cumulative Malmquist index of TFP change decomposed into efficiency change and technical change for grain and potato farms, 1976-1989

Year	Grain farms			Potato farms		
	Efficiency change	Technical change	TFP change	Efficiency change	Technical change	TFP change
1976	1.000	1.000	1.000	1.000	1.000	1.000
1977	0.860	1.083	0.931	1.201	0.795	0.955
1978	0.824	0.818	0.674	1.284	0.557	0.714
1979	0.881	1.020	0.898	1.328	1.002	1.329
1980	0.717	0.786	0.564	1.335	0.505	0.674
1981	0.926	0.678	0.627	1.018	0.608	0.618
1982	0.764	0.775	0.592	1.187	0.779	0.923
1983	0.859	0.954	0.819	1.280	0.834	1.067
1984	0.606	1.046	0.634	1.349	0.810	1.092
1985	0.925	0.835	0.772	1.505	0.776	1.166
1986	0.898	0.756	0.679	0.925	0.921	0.850
1987	0.964	0.733	0.707	1.267	0.726	0.917
1988	0.833	0.893	0.744	1.374	0.575	0.788
1989	0.992	0.758	0.753	1.425	0.749	1.065
Total change (per cent)	-0.8	-24.2	-24.7	42.5	-25.1	6.5

meteorological stations were too general to account for possible weather effects on farm-level performance. In consequence, it was assumed that over the whole study period of 14 years, the overall effects of weather on farms were neutral.

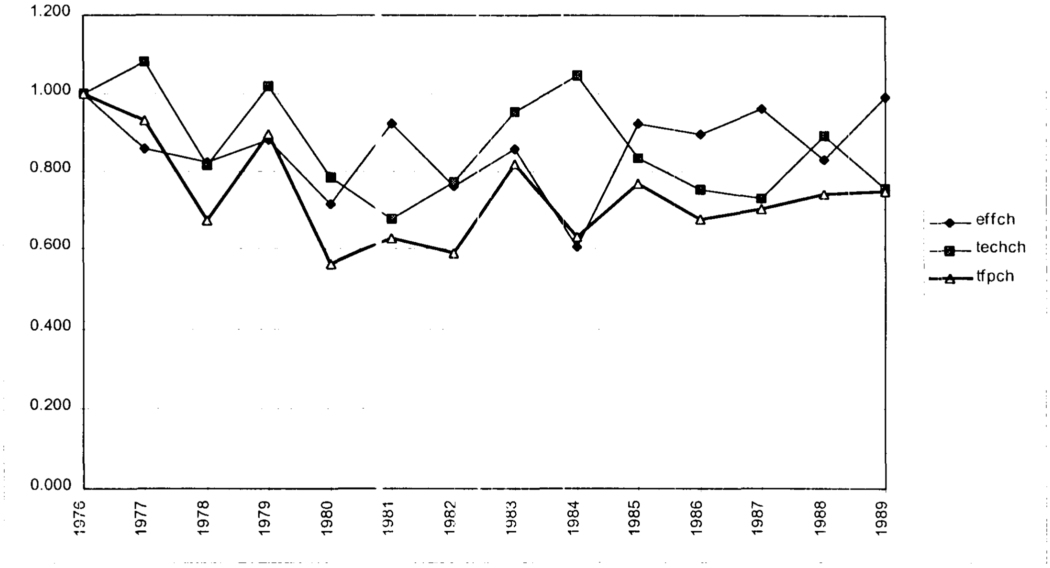
[6] The three different policy sub-periods as defined in earlier chapters were used here, i.e., 1976-1980, 1981-1985, 1986-1989.

suggests some consistent patterns in TFP change. In the first sub-period, TFP declined due to both technical regress and efficiency deterioration. In the second sub-period, TFP mildly increased, and this was due to efficiency improvements whereas a slight decline in technical change was observed at the end of the period. In the third sub-period, the TFP continuously increased and, again, this was primarily due to improvements in efficiency. Slight improvement in technical change was observed at the end of the period.

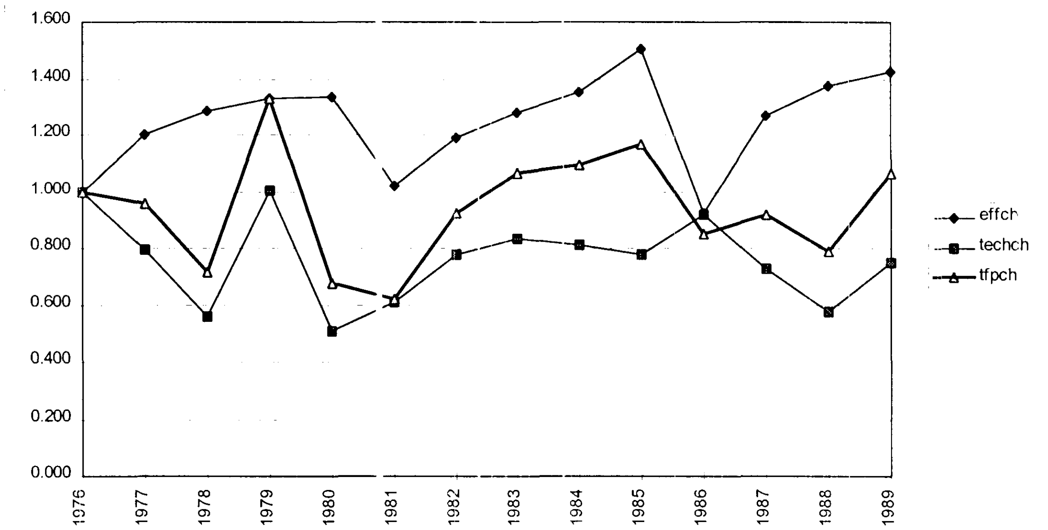
In the case of potato farms (Figure 7.2(b)) the trends of TFP change and its elements were less ambiguous: In the first sub-period, TFP decline was observed despite year-to-year fluctuations. This decline was primarily due to decline in technical change. In contrast, efficiency consistently increased throughout the whole period which was, however, perhaps not enough to bring the TFP up. In the second period, TFP increased markedly due to increases in both technical change and efficiency. In the third sub-period, TFP increased mildly. Here again, technical change and efficiency change moved in opposite directions. The significant improvement in efficiency dominated the deterioration in technical change.

Figure 7.2 **Cumulative Malmquist index of TFP change decomposed into technical change and efficiency change for grain and potato farms[a], 1976-1989**

(a) grain farms



(b) potato farms



[a] effch - Efficiency change.
techch - Technical change.
tfpch - TFP change.

7.4 Comparison of Results from Data Envelopment Analysis and Stochastic Frontier Production Function Approaches

As mentioned earlier, the primary purpose of running DEA-based models was to test the robustness of the SFPF model results which are the core analyses of the current study. This section compares the model results from the DEA-based efficiency and TFP measures with those of the SFPF models reported in Chapters 5 and 6.

Table 7.5 compares the average efficiency scores under DEA and SFPF models. In the grain case, the average efficiency scores of the individual sub-periods under alternative models were very similar (in the first sub-period, the efficiency scores were identical), whereas in the potato case, the average efficiency scores under the DEA models were slightly higher than those obtained using the SFPF models. This is perhaps due to the fact that DEA models envelope the observations in a more flexible way (hence yielding higher efficiency scores) than the SFPF models.[7] In both the grain and potato cases, the DEA efficiency scores consistently increased over time but the SFPF efficiency scores fluctuated over time.

Table 7.6 compares the annual changes in TFP between DEA and SFPF models for both the grain and potato farms.

In the grain case, TFP changes under the Malmquist index and SFPF were found to be fairly comparable in terms of both direction and magnitude: TFP declined annually by 2.0 and 1.7 per cent under the Malmquist index and SFPF approaches,

[7] It is possible that the average efficiency scores from DEA may be lower than those of SFPF if the effect of accounting for data noise exceeds the countervailing effect of the added flexibility provided by the DEA frontier.

Table 7.5 Comparison of mean efficiency scores between DEA and SFPF results in grain and potato farms, 1976-1980; 1981-1985; 1986-1989

Period	Grain farms		Potato farms	
	DEA[a]	SFPF	DEA[a]	SFPF
1976-1980	0.804	0.804	0.797	0.734
1981-1985	0.815	0.829	0.803	0.723
1986-1989	0.852	0.824	0.783	0.752

[a] Here, the pure technical efficiency scores (calculated under VRS technology) of DEA were used for comparison purposes because in most SFPF cases the translog functional forms with no restrictions on returns to scale were used.

Table 7.6 Comparison of annual average rates of TFP change and its components between DEA and SFPF results in grain and potato farms, 1976-1989

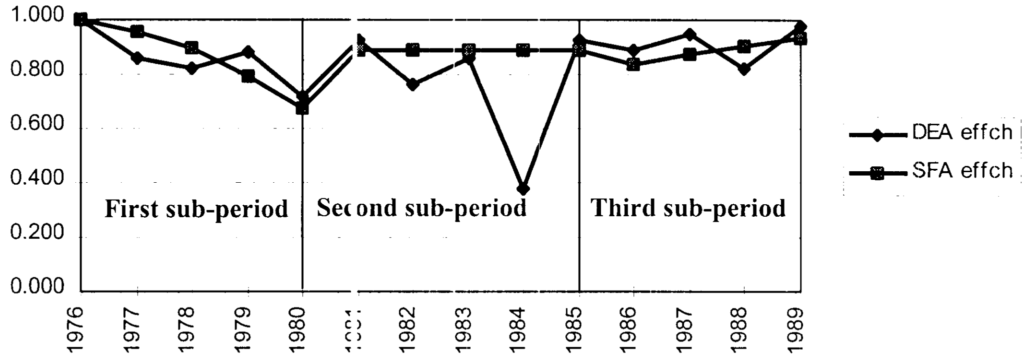
Measure	Grain farms		Potato farms	
	DEA	SFPF	DEA	SFPF
Eff. change	-0.2	-0.5	2.8	-0.2
Tech.change	-1.9	-1.3	-2.2	1.1
TFP change	-2.0	-1.7	0.5	0.8

respectively. Technical change per annum declined by 1.9 per cent under the Malmquist index and 1.3 per cent under SFPF. Efficiency per annum declined by 0.2 per cent under the Malmquist index and by 0.5 per cent under the SFPF approach. In the potato case although both the Malmquist and SFPF approaches produced a comparable TFP change (0.5 per cent and 0.8 per cent TFP increase per annum under Malmquist and SFPF respectively), their individual components differed substantially from one another. Annual decline of technical change of 2.2 in the Malmquist case was contrasted against annual increase of technical change of 1.1 in the SFPF case. Next, an annual rate of efficiency increase of 2.8 per cent under the Malmquist index contrasts with an annual rate of efficiency decline of 0.2 per cent under SFPF.

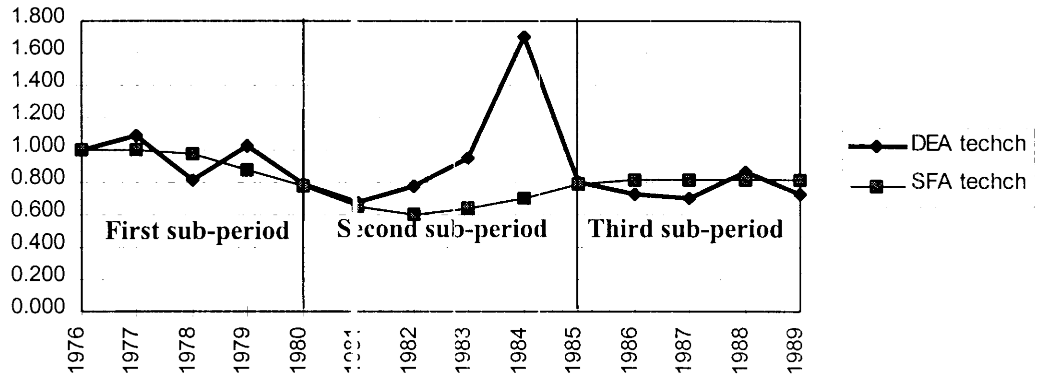
Finally, Figures 7.3 and 7.4 compare for grain and potato farms, respectively, the trend patterns of TFP change and its components under the DEA and SFPF approaches. In most cases the trend patterns of efficiency change, technical change and TFP change were found to be similar for the two approaches despite the more year-to-year fluctuating pattern in the DEA case. However, some divergence in the trend patterns of potato farms was observed: (i) while the efficiency in the first sub-period increased under the DEA, it decreased under SFPF (ii) while technical regress was observed in the first and third sub-periods and some technical progress was observed in the second sub-period under DEA, almost no any technical change was observed throughout the whole period except for 1980/1981 and 1985/1986 when some technical progress then regress occurred respectively. SFPF, . The overall similarity in the changing patterns of TFP and its individual components under the two different model specifications (DEA and SFPF) suggests that the results of the SFPF models are fairly robust.

Figure 7.3 Comparison of the trends in TFP and its components between DEA and SFPF approaches: grain farms, 1976-1989

(a) Efficiency change



(b) Technical change



(c) TFP change

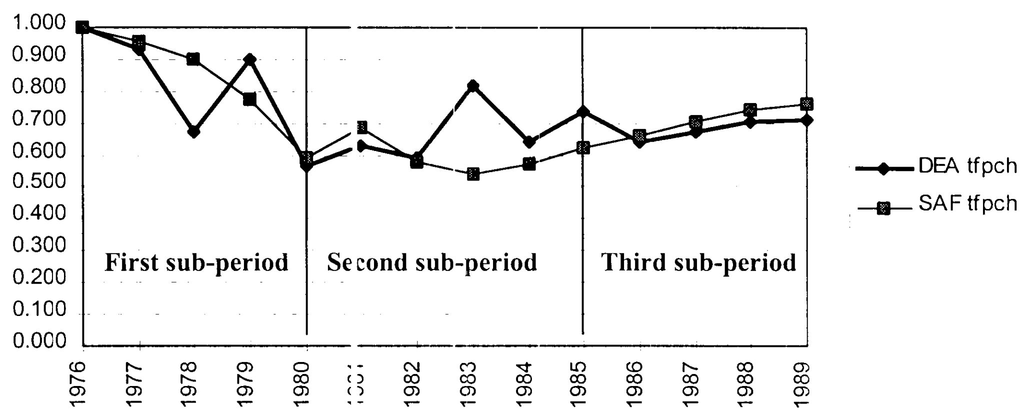
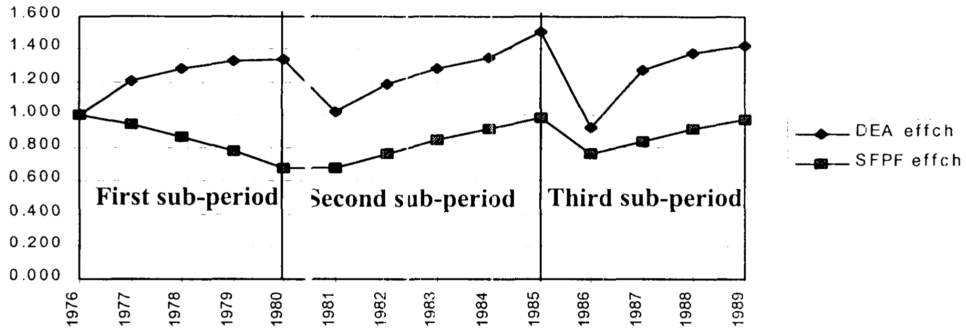
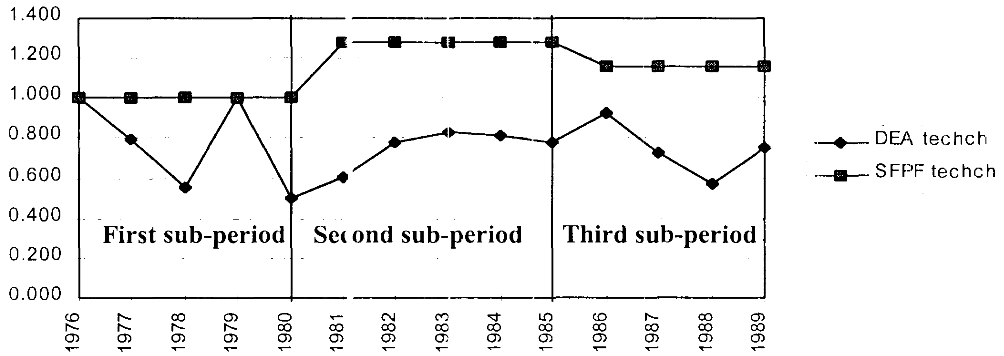


Figure 7.4 Comparison of the trends in TFP and its components between DEA and SFPF approaches: potato farms, 1976-1989

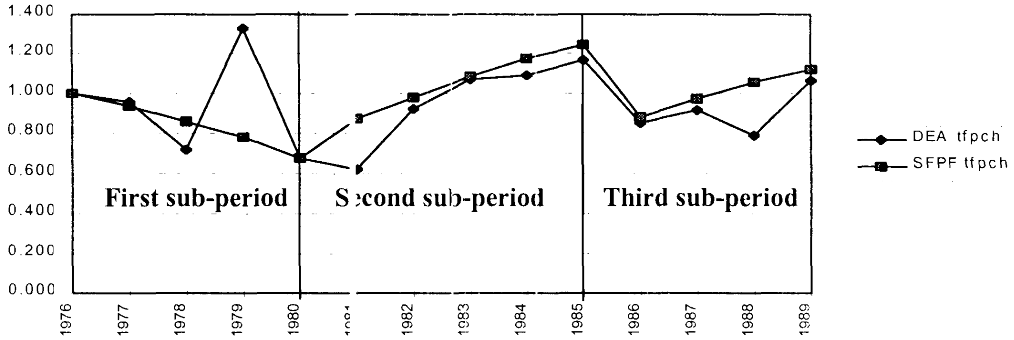
(a) Efficiency change



(b) Technical change



(c) TFP change



7.5 Summary and Conclusions

The results of the DEA-based models presented in this chapter suggest that the average efficiency levels of both grain and potato farms were rather low throughout the whole period. The analysis revealed that, in both the grain and potato cases, poor pure technical efficiency contributed more than scale efficiency to the overall low efficiency levels. It was also suggested that the majority of grain and potato farms were operating under either CRS or IRS. These results give no evidence of grain and potato farms being too large (as was often claimed).

In the cases of both grain and potato farms, the overall TFP change was rather disappointing: 25 per cent of TFP decline in grain and less than seven per cent of TFP increase in potato farms over the entire 14-year study period 1976-1989. For both grain and potato farms, the main factor contributing to the decline in TFP was the decline in technical change. Total decline of technical change of 24 and 25 per cent occurred in grain and potato farms, respectively, over the period 1976-1989. In terms of efficiency change, while a less than one per cent decline was observed in grain farms, a substantial 43 per cent increase of efficiency occurred in potato farms which eventually caused the overall increase of TFP.

Here, the potato case clearly demonstrates that the individual elements of technical change and efficiency change can have opposite effects on overall TFP change, the determination of which has important policy implications.[8] This result seems to conform to that of Koopman (1989) for Soviet agriculture, and to that of Moroney and Lovell (1991) for centrally-planned economies who found that the main problem lies not in a static level of low efficiency but rather in lack of technical change. However, this contradicts the results of Carter and Zhang (1994) for centrally-planned agriculture and Easterly and Fischer (1995) for the Soviet economy where significant technical progress was reported. Despite these

[8] For instance, low and deteriorating efficiency levels of farms may suggest the need for economic reform and improved skills of managers and farmers, whereas the lack of technical progress may suggest the need for investment into research and development and importation of new technology.

interesting results, the above DEA-based results of efficiency and TFP change found in the present study must be interpreted with caution as they have not accounted for any errors associated with either fluctuating weather or quality of data. The frequently fluctuating pattern of changes in TFP and its components perhaps demonstrates the sensitivity of the results to possible data errors and weather shocks.

Comparison of the efficiency and TFP scores of the two different approaches (DEA-based and SFPF-based) suggests that, despite different methodological bases, efficiency scores of the two models were similar for both the grain and potato cases. In terms of TFP change, in the grain case, the overall change of TFP and its individual components calculated under the two different models were surprisingly similar, whereas in the potato case, the relative contributions of technical efficiency change and technical change were found opposite.

To conclude, the comparisons of the two sets of models (DEA and SFPF-based), the similar scores of efficiency measures and TFP changes in the case of grain farms and the overall matching patterns of changes in efficiency, technology and TFP in the cases of both grain and potato farms suggest that the results of SFPF analysis in Chapters 5 and 6 are robust and fairly reliable.

8. Synthesis

8.1 Introduction

This chapter summarises the results and findings of the current study. It also presents some policy implications and suggestions for further research. The chapter is organised as follows: Section 8.2 summarises the main results of the individual chapters and draws conclusions. Section 8.3 presents policy implications resulting from the findings of this study of Mongolian crop farming in the context of current radical reform. Finally, Section 8.4 makes some suggestions as to further research.

8.2 Summary of Findings and Conclusions

Crop farming in Mongolia is a non-traditional sector that has been significantly expanded over the last four decades. It is characterised by low yields and riskiness due to high altitude, uncertain harsh climatic conditions and the absence of domestic production of such important agricultural inputs as machinery, fertiliser and chemicals. The principal crops are grain (85 per cent wheat, with the remainder barley and oats) followed by potatoes and other vegetables.

Despite technical and economic limitations, the Ministry of Agriculture allocated substantial resources to the crop sector over the last two decades in order to boost agricultural production. As a result, in the second half of the 1980s, self-sufficiency was achieved in basic staples such as grain, potatoes and other vegetables.

This self-sufficiency was achieved by a number of centrally-planned development initiatives that basically fell into three categories: (i) increased use of conventional inputs, (ii) the development and importation of new technology and (iii) a series of policy reforms aimed at improving farm efficiency. The emphasis of these development initiatives differed in individual policy sub-periods.[1] During the first sub-period (1976-1980) output growth was ensured mostly by increased use of conventional inputs. During the second (1981-1985) and third (1986-1989) sub-periods, the Ministry of Agriculture began shifting its policy from a so-called "extensive" to an "intensive" growth strategy (Ulziibat, 1992). The emphasis of the new approach was the increased role of new technology, investment in human resources and the introduction of incentive systems (Unen, 1986) with the aim of improving farm productivity levels. In particular, during the last four years (1986-1989) of the centrally-planned economic regime, several new forms of farm incentive systems aimed at improving farm performance were experimented with within the state farm structure (Ministry of Food and Agriculture, 1990b). This was a reflection of the new wave of Gorbachev's economic reform, "Perestroika", which was carried out throughout the Eastern Bloc.

Despite all the intensification measures and various reform attempts and, ironically, some improvements in farm productivity and performance indicators recorded in official government documents (Ministry of Food and Agriculture, 1990b; 1991), the unprecedented radical economic reforms actually took place in 1991 and were based on economic arguments.

While some recent studies reported that existing technology in crop farming was obsolete and inadequate (Ulziibat, 1992; Ulrich, 1994), others found that the main problem facing the crop sector was poor management and organisational deficiency within the farm (Dixon, 1989; United Nations Development Programme, 1992). The latter argument suggested a somewhat low level of efficiency in Mongolian crop farming. Hence, the technological status and efficiency levels of crop farms of this pre-reform period are not known.

[1] The current study covers the fifth (1976-1980), sixth (1981-1985) and seventh (1986-1989) five-year plan periods of the national economy of Mongolia. These are referred to here as the first, second and third sub-periods respectively.

Except for China, only a few studies related to productivity and efficiency issues have been carried out for the former centrally-planned agricultures. These studies often had controversial findings and frequently found against the prevailing course of development (Carter and Zhang, 1994; Johnson *et al.*, 1994; Brada and King, 1993; Koopman, 1989). Moreover, the majority of these analyses looked at agricultural efficiency and productivity issues using aggregated national-level data. Hence the current analysis of farm-level data may provide valuable insights that may have been masked by aggregation effects in previous studies. Given the fact that Mongolian crop farms were almost exact prototypes of Soviet Sovkhozy (i.e. state farms) in terms of structure and functioning, and also that there has been a striking similarity in policy change patterns in Mongolian and Soviet agriculture, this analysis of Mongolian farm-level data may also provide additional knowledge of the characteristics of pre-reform Soviet-style agricultural enterprises.

The main purpose of this study was to investigate some of the productivity and efficiency issues of grain and potato farming (which are the most important crops) in Mongolia in the period 1976-1989.

The main objectives of the current study, as formulated in Chapter 1, were to:

(i) measure the extent of and changes in, technical efficiency and technical progress and total factor productivity (TFP) of grain and potato farms for the period 1976-1989;

(ii) measure and analyse factors affecting efficiency levels;

(iii) investigate the scale economies; and

(iv) draw policy implications related to the current development of Mongolian grain and potato farming.

In order to attain the objectives stated above, some preliminary investigation was undertaken to highlight the research problems and identify adequate analytical methods for the study. This investigation covered the literature reviews of efficiency and productivity measurement techniques (Chapter 2), empirical studies on efficiency and productivity issues of centrally-planned agriculture (Chapter 3), and an exploration of farm structure and development alternatives practised in Mongolian crop farming as well as a discussion of the data and variables used in this study (Chapter 4).

As a result of the preliminary investigation, two different analytical approaches were selected for the current study: the stochastic frontier production function (SFPF) approach and the data envelopment analysis (DEA) approach. While the SFPF approach was considered as the main analytical approach and used to analyse efficiency and productivity issues of grain (Chapter 5) and potato (Chapter 6) farms, the DEA approach was used primarily to check the robustness of these SFPF results (Chapter 7).

Within the SFPF framework, two inefficiency-effects models were used: the time-varying inefficiency-effects model (Battese and Coelli, 1992) and the technical inefficiency-effects model (Battese and Coelli, 1995). While the first model aimed at estimating efficiency scores and establishing efficiency trends in grain and potato farms over the period 1976-1989, the second model aimed at explaining the efficiency variations among farms in terms of certain farm-specific socio-economic variables. Due to limited data availability, the latter model was only applied to grain farms and only for the period 1987-1989.

The specification of the SFPF models for the Mongolian grain and potato farms was conducted using a two-stage specification procedure similar to that of Kumbhakar and Hjalmarsson (1993). This was used for identification of the production technology and the inefficiency-effects models. In the first stage, an adequate production technology was identified through a set of statistical tests on various modifications of the translog function. In the second stage, the specification of the inefficiency term was determined, again by using a set of statistical tests on various forms of inefficiency terms. The final set of preferred models determined by the two-stage testing procedure was then estimated. Choice of this two-stage testing procedure serves a double purpose. First, thorough specification of the functional forms and inefficiency terms avoids possible bias in the final results. Second, it also allows the researcher to investigate the impact of alternative functional forms and inefficiency specifications on farm efficiency estimates.

To reflect the important policy benchmarks, in both the grain and potato cases the 14-year study period was divided into three policy sub-periods (1976-1980, 1981-1985, 1986-1989) and SFPF models were run separately for each of these.

Once information on efficiency change and technical change of the farms became available from the SFPF models, it was used to calculate the TFP change of the farms in a similar fashion to that of Nishimizu and Page (1982) and Perelman (1995). The SFPF-based approach is capable of capturing both efficiency change and technical change as components of productivity change. This contrasts with the productivity measurement methods involving index numbers (e.g., Tornqvist indices) and aggregate production analyses, which ignore efficiency effects, thereby resulting in potential biases (Grosskopf, 1993). The decomposition of TFP changes into efficiency changes and technical changes introduces an additional dimension to the analysis from the policy perspective. This is because these components often entail different policy recommendations (Nishimizu and Page, 1982; Perelman, 1995).

In the DEA framework, the basic DEA model for the case of variable returns-to-scale (VRS) technology was run for grain and potato farms for the period 1976-1989 to calculate efficiency scores of individual farms. Next, to calculate the scale efficiencies of individual farms, an additional DEA model for the case of constant returns-to-scale (CRS) technology was estimated. The scale efficiency of a particular farm was then calculated as the ratio of efficiency scores under CRS and VRS technologies. Also, to obtain some information on the economies of scale of individual farms, a third DEA model was calculated for the case of non-increasing returns-to-scale (NIRS) technology. Then the efficiency scores under three different technologies, i.e., VRS, CRS and NIRS were used to identify the economies-of-scale regions at which individual farms are operating. Following this, additional inter-period DEA models were calculated to construct the Malmquist index of TFP change for grain and potato farms. The Malmquist index of TFP change calculates the TFP change decomposed into its components: efficiency change and technical change (Färe, Grosskopf, Norris and Zhang, 1994). The efficiency scores and TFP changes from DEA were then compared to the SFPF results to test the robustness of the results of the latter model.

The following is a brief summary of the SFPF model results:

1) Both grain and potato farms were characterised by statistically significant inefficiencies in all policy sub-periods. Relative to a maximum efficiency score of one, the average efficiency scores of grain farms in the first, second and third sub-periods were 0.804, 0.829 and 0.824 respectively, and those for potato farms were 0.734, 0.723 and 0.752 in the first, second and third sub-periods respectively. Compared to other studies of centrally-planned agriculture that used the SFPF approach, these efficiency scores appear to be in the upper range. Interestingly, in those cases of centrally-planned agriculture where a more general functional form is used (Danilin *et al.*, 1985-CES; Koopman, 1989-Translog; Koopman, 1990-Translog; Fan, 1991-Modified Translog) the efficiency levels were higher[2] than in the cases where the simple Cobb-Douglas functional form was used (Tran *et al.*, 1993; Johnson *et al.*, 1994; Brock, 1996). The current study found that the selection of functional form affects the efficiency scores and moreover, in four out of six sub-period cases, the efficiency scores of the translog function were higher than those of the Cobb-Douglas. So, the relatively low level of efficiency scores found in some of the studies on centrally-planned agriculture could have been partly due to the fact that more restricted functional forms were used. Farm efficiencies in both grain and potato farms, however, had increasing trends over time. This was particularly so towards the end of the 1980s when a major incentive reform was

[2] The exception here is Hofler and Payne (1993), where SFPF using the Cobb-Douglas form yielded high efficiency scores, i.e. 0.929 in the private sector and 0.889 in social sector of Yugoslavian agriculture.

implemented for the grain and potato farms. During this latter period, various forms of tenancy systems were introduced to give the producers incentive and the farm managers a higher autonomy, which was a part of a much wider restructuring policy carried out throughout the Eastern Bloc known as "Gorbachev's Perestroika"(see more detailed discussion on the new farm policies in Chapter 4). In contrast, however, findings by Brock (1996) in the case of Russian agriculture and Johnson *et al.* (1994) in the case of Ukrainian agriculture indicated declining efficiency trends of farms in the late 1980s and early 1990s.

2) Poor technical progress was a major problem over the period 1976-1989: grain farms experienced technical regress in the first and third sub-periods and only some technical progress in the second sub-period and potato farms experienced the absence of technical change in all sub-periods with only few exceptions.[3] This result seems to be similar to that of Koopman (1989), Johnson *et al.* (1994) but dissimilar to that of Carter and Zhang (1994) for the case of centrally-planned agriculture.

3) The efficiency levels of grain farms over the years 1987-1989 were positively related to the levels of technical education and experience of farm workers, the degree of management autonomy and the extent of Soviet technical assistance. This may suggest that government investment in human capital, the successive incentive reform attempts and Soviet technical assistance may have been translated into a higher farm performance. The findings that farms with better natural conditions displayed higher efficiency levels (based on the time-varying inefficiency effects model for grain and potato farms in the period 1976-1989) could be due to the fact that the farm workers in more favourable natural conditions were better motivated than others. In contrast, several previous studies (Tran *et al.*, 1993; Brock, 1996) on other centrally-

[3] A significant technical progress was observed in 1981 and a slight technical regress was observed in 1986.

planned agriculture could not establish any significant relationship between land quality and farm performance.

4) The efficiency scores of large and medium farms were consistently higher than small farms. This is perhaps due to the fact that, under the extremely difficult natural conditions of Mongolia, the large crop farms which are usually better equipped with capital and machinery were able to cope better with natural adversity, thereby yielding an overall higher performance than medium or small farms.

5) Moderately increasing or constant returns to scale characterised both grain and potato farms. This result is similar to that of Gray (1984) and Johnson *et al.* (1994) for the case of Ukraine, but contradicts Brock (1996) who found decreasing returns to scale for Russian state farms.

6) In the case of grain farms, the partial output elasticities with respect to capital and land were highest, whereas in the case of potato farms the partial output elasticities with respect to land and labour were highest. This result seems to support the relevance of government policy of that time of increasing output by way of increased investment of capital, further expansion of land and increased labour force. The estimated output elasticities with respect to fertiliser were the lowest. This perhaps reflects the incorrect use of this important production input and is in line with the findings of earlier studies on grain production by the World Bank (1995) and Ulziibat (1992) which suggested that the impact of fertiliser use in grain production was minimal.

7) In the case of grain farms, a 23.6 per cent TFP decline was observed over the 14-year period, more than three-quarters of which was due to technical regress and the rest due to efficiency decline. However, a closer look at the specific time patterns of TFP change reveals that an initial sharp decline of TFP was followed by improvement of TFP starting in 1983. In the period 1983-1989, a 41.7 per cent increase in TFP was observed due to both technical progress and efficiency increase.

8) In potato farms a 11.6 per cent TFP increase was observed over the 14-year study period. This was primarily due to 15.5 per cent of technical progress which was moderated by a 3.4 per cent efficiency decline. Again a similar TFP change pattern over time was observed here as in the grain-farm case. After a sharp decline from 1976 to 1980, TFP consistently increased until 1989 resulting in 65.1 per cent TFP improvement.

9) The DEA-based efficiency scores and TFP estimates broadly supported the SFPF results. The efficiency scores of the two approaches were comparable. The changes of TFP and its individual components (technical and efficiency changes) calculated under the alternative approaches (i.e., SFPF and DEA-based) were very close in the grain case but less so in the potato case. In the latter case, although under both approaches the signs and the magnitude of TFP change were similar, the directions of the individual components of TFP change differed markedly from one another: while SFPF results suggested that there was significant technical progress and some efficiency decline, the DEA-based results suggested the opposite. In terms of the trends in TFP change and its components, results of both methodologies were also very similar;

In addition to the empirical results stated above, some methodological findings were made:

10) In most grain and potato farm cases the more general functional form, i.e. the translog, was preferred to the Cobb-Douglas. However, as reviewed in Chapter 3, the majority of empirical studies conducted on former centrally-planned economies employed the Cobb-Douglas without a priori justifications In the context of centrally-planned economies, the use of more general functional forms is of particular importance given the fact that, in a few past studies, shifting from simple to more complex functional forms often reversed the research findings – see Weitzman (1970), Desai (197[illegible]) and Easterly and Fischer (1995). In those studies the CES functional form was used, which is more flexible than Cobb-

Douglas but still restrictive compared with the translog functional form used in the current study. For instance, in the CES case, the elasticity of substitution between the inputs is constant whereas in the translog it is not constant.

11) Efficiency results of the SFPF with the time-varying inefficiency effects models were robust compared to efficiency results of the DEA models. This was perhaps because of the SFPF's ability to accommodate for stochastic noise in the data.

12) Choice of functional form and specification of the inefficiency term do affect the efficiency scores of individual farms. However, the former seemed to have more effect on the inefficiency scores and their distribution than did the latter. This implies that a proper specification of production technology is necessary to obtain reliable results.

13) Frequent fluctuations in TFP change and its components under the DEA approach suggested that this approach is prone to influence from data errors and climatic shocks. An attempt to accommodate weather shocks was not successful due to lack of reliable data. Recent developments in stochastic DEA modelling (such as the work of Land et al., 1993; Banker, 1996; Grosskopf, 1996; and Simar, 1996) may give some opportunity to deal with this problem.

14) Despite the different methodological underlyings of the DEA-based and SFPF approaches, the results of the DEA-based models supported most of the findings of the SFPF models, thus suggesting that the results of the latter models are robust.

15) In most cases, technical efficiency scores calculated under DEA were slightly higher than those under the SFPF models. This may be due to the fact that DEA envelopes the data in a more flexible manner than SFPF (thus producing higher efficiency scores).

16) DEA results suggesting that the majority of grain and potato farms were operating under increasing returns to scale validate the SFPF results on returns to scale.

17) The signs and magnitudes of the TFP change and its individual components (technical change and efficiency change) calculated under alternative methodologies (DEA-based Malmquist index and SFPF) were comparable in the case of grain farms but less so in the case of potato farms.

18) The overall trend patterns of TFP change and its individual components were quite similar under the DEA-based and SFPF methodologies.

8.3 Policy Implications

Due to the different economic settings under which Mongolian crop farms have been operating since 1991, it is not easy to draw direct policy implications for the current situation from the model results based on the pre-reform[4] farm performance.

It would seem, however, that many problems facing the farming sector at present may be explained in the context of the legacy of the previous centrally-planned economy. As privatization took place, most crop farms continued to function as the prior state farms had in terms of their structure and technology but with reduced size (World Bank. 1995) and perhaps different objective functions. Moreover, the current crop farms possess essentially the same human and material resources as did the old state farms and also the same management skills since state farm managers were appointed/elected as the directors of the new crop companies. Therefore, it can be assumed that economic analysis of crop farming in

[4] The reform here refers to the radical economic reforms away from central planning and state ownership that have taken place since 1990.

the pre-reform period may have certain policy implications for the current farming situation.

In order to discuss the relevance and possible policy implications of this study for the current crop sector, some detailed examination of the post-1990 developments is needed.

The radical economic reform of the 1990s brought into the Mongolian crop sector a mass privatization and enterprise restructuring of unprecedented scale. The liberalisation of trade, price and exchange rates and consequent hyper-inflation significantly affected the performance of the sector (Asian Development Bank, 1995, p. 4). As the data of Table 8.1 illustrate, the reform process was followed by a sharp decline in sown area and production. The area planted for grain dropped from 654 000 ha in 1990 to an estimated 391 000 ha in 1994. The grain output fell from 721 000 tonnes in 1990 to 331 000 tonnes in 1994.

By 1994, the level of grain output had fallen back to the level of the mid-1960s. The area planted for potato production fell from its record level of 11 800 ha in 1990 to 7 400 ha in 1994, and output level fell from 129 200 tonnes in 1990 to 55 000 tonnes in 1994.

This dramatic drop in production levels since the economic reform of 1991 can be attributed to two main reasons (Chalmers, 1993).

Table 8.1 Sown area and output of grain, potato and vegetables, 1965; 1985; 1990-1994

Year	Sown area (000 ha)			Output (000 t)		
	Grain	Potato	Vegetable	Grain	Potato	Vegetable
1965	419.9	2.7	1.3	322.0	24.4	10.6
1985	634.6	9.0	3.0	890.2	106.3	36.7
1990	653.9	11.8	3.3	721.5	129.2	35.4
1991	617.5	9.3	2.3	596.2	95.1	22.4
1992	592.8	8.2	1.9	493.8	76.9	14.6
1993	504.2	8.5	2.9	480.1	58.4	23.0
1994	390.9	7.4	2.5	330.8	55.0	23.0

Source: Ministry of Food and Agriculture (1994a), Ulaanbaatar.

One is the short-term problem associated with temporary shortage of imported inputs[5] and difficulties associated with the availability of working capital. The other is the structural problem inherited from the previous centrally-planned system.

The more fundamental structural problems were perhaps associated with farm efficiency, the technology used on farms, and distortions in farm locations caused by the fact that a large proportion of farms was built on land that was marginal, both agronomically and economically. The major explanation given for these problems was the government's official policy of self-sufficiency in staple crops

[5] The level of imported inputs crucial for crop farming fell drastically. This was mostly due to the sudden depreciation of the local currency followed by liberalisation of the exchange rate (Chalmers, 1993). Compared to the average annual importation of chemical fertiliser of 71 400 tonnes for the period 1986-1990 during the period 1991-1994 only 8400 tonnes of fertiliser were imported annually. In the five years 1986-1990, a total of 5 396 new tractors were imported, a rate of over 1 000 per year. In contrast, in the period 1991-1994 only 710 tractors, or fewer than 180 tractors per year, were imported (World Bank, 1995).

which proved to be inadequate and not viable in today's economic circumstances (World Bank, 1995; Asian Development Bank, 1995). The standard and adequacy of Soviet production technology, which still constitutes the core of crop farming technology in the country, is not clear today. While some studies have cast doubt on its adequacy (Ulrich, 1994; Ulziibat, 1992), others have assessed it as inherently sound (United Nations Development Programme, 1992). However, no formal study of the viability of existing technology and its improvement over time has yet been undertaken.

Several observations can be made on recent developments in the crop sector in light of these structural problems:

a) Since the reform started in 1991, a massive amount of crop land has been abandoned[6] and, ironically, in many cases this occurred in some of the most favourable cropping regions of the country. According to a recent World Bank (1995) study, in the four years 1991-1994 of the current economic reform, a total 301 000 ha of crop land (almost half the total sown area of the pre-reform period) was abandoned, the largest part of which are from the Selenge-Onon agro-ecological region (the most fertile land region). As Table 8.2. shows, during the first two years of the reform, a total of 151 000 ha of crop land was abandoned, almost 40 per cent of which was from the Selenge-Onon agro-ecological region.

The Ministry of Agriculture, concerned with the deterioration of self-sufficiency in basic staple crops attained before 1990, attempted to reverse this trend by providing subsidised loans to all grain farms and by imposing punitive measures on those farms which abandoned their crop land (Ministry of Food and Agriculture, 1993) but without much success (Asian Development Bank, 1995). The Ministry of Agriculture persevered with this policy despite recent studies by the World Bank (1995) and Asian Development Bank (1995) which concluded that the current government policy of maintaining self-sufficiency in production of

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[6] The abandoned land refers to previously cultivated land suitable for cropping which, for short- and long-term economic reasons, has been left idle.

staple crops is not feasible under the new conditions of economic rationalism and a competitive environment. If the Ministry of Agriculture were to revise its policy target of food security through self-sufficiency and to support only those enterprises with a better chance of survival and success (as suggested in the two studies mentioned above), then it needs some empirical information to guide its decisions.

The current study of the immediate pre-reform period may be useful here. The study established a positive relationship between farm agro-ecological conditions and efficiency levels. This may be explained as the result of better motivation of farmers working under favourable conditions and by the fact that there were certain distortions in farm locations driven only by the output target systems of the pre-reform period. The substantial information on the efficiency levels of individual farms and regions produced in the present study may serve as the basis for a focused government policy of identifying which farms may have a better chance of survival under the new conditions. Also, the estimated production function parameters that have been produced in this study provide detailed technical information which will be invaluable in future analyses of agricultural policy options in Mongolia.

b) As a result of privatisation, the farms were divided into much smaller units on the basis of economic arguments that the old state farms were too big to manage efficiently. For instance, shortly after the first wave of privatisation, by November 1992, 85 per cent of crop farms had less than 5 000 ha of crop land and they held 50 per cent of the total crop land, whereas the number of grain farms had increased almost four times compared with the 1990 level (Asian Development Bank, 1994). Then, because of growing concerns that the new grain farms were too small, in 1994 the Ministry of Agriculture moved to amalgamate the smaller crop companies back into larger entities with a minimum size of 6 000 ha of crop land (Ministry of Food and Agriculture, 1993; Asian Development Bank, 1994, p. 32).

The current study of the immediate pre-reform period does not supply any evidence of scale problems in predominantly large-scale farms.

Table 8.2 Abandoned land by agro-ecological region and province, 1992

Agro-ecological region	Province	Area (000 ha)
Hangai-Huvsgul	Arhangai	9.3
	Huvsgul	9.2
	Bulgan	9.1
	Zavhan	8.4
	Sub-Total	36.0
Selenge-Onon	Tuv	24.6
	Selenge	12.7
	Bulgan	9.1
	Arhangai	9.4
	Uvurhangai	4.0
	Sub-Total	59.8
Altai	Uvs	2.8
	Bayan-Ulgii	1.5
	Hovd	0.7
	Zavhan	8.4
	Govi-Altai	0.8
	Sub-Total	14.2
Steppe	Dornod	5.6
	Hentii	21.0
	Sukhbaatar	8.2
	Dorno-Govi	0.1
	Dund-Govi	0.3
	Sub-Total	35.2
Govi'	Umnu-Govi'	0.4
	Govi-Altai	0.8
	Bayanhongor	0.3
	Uvurhangai	4.0
	Dund-Govi	0.2
	Dorno-Govi	0.1
	Sub-Total	5.8
	TOTAL	151.0

Source: World Bank (1995).

In addition, the study also concludes that large and medium farms performed better than small farms in terms of efficiency. This may explain why the large farms were reluctant to split into smaller units and why recent Ministry of Agriculture action reversed this fragmentation.

c) The sudden shock of the radical reforms created unfavourable economic conditions in the crop sector, thus forcing a large number of skilled workers, previously trained and employed in the crop sector, to leave the farming sector in search of other work. Recent surveys show that after only six years since reforms began in 199?, a mere five per cent of the professionally trained agronomists and crop workers previously engaged in the crop sector remained there (Dorj, 1996).

The results of the current study suggest that there was a strong relationship between farming experience and professional training on the one hand and farm efficiency on the other hand in the pre-reform period. This may imply that in order to counteract the current decline in farm efficiency and productivity, the Ministry of Agriculture should implement policies to keep experienced and well-trained agricultural professionals in the sector.

d) A number of post-reform development projects initiated by donors (World Bank, 1995; Japan Agricultural Land Development Agency, 1995) suggested that the technology in crop farming is obsolete and as such is a major deficiency. These projects propose the import of new technologies from developed countries with comparable climatic conditions such as Canada and U.S.A. (Ulrich, 1994). However, currently the Ministry of Agriculture, primarily concerned with the high prices of Western machinery and technology, is reluctant to divert its existing limited resources to the development and importation of new technologies. Instead it favours further use of Soviet technology in the crop sector.

The findings of the current study support the development initiatives of the donor projects: in the 14 years until 1989, grain farms were characterised by a substantial lack of technical change. This was the main cause of TFP decline. Therefore, the recent donor efforts to encourage the Ministry of Agriculture to invest in new technology may be justified by the expectation of achieving a further increase of TFP in the sector.

8.4 Suggestions for Further Research

Several suggestions can be made for possible future research arising from the present study:

1) A pre- and post-reform period comparative analysis of efficiency and productivity in the crop sector should be undertaken as soon as reliable data on the post-reform period become available.

2) If the relevant data can be obtained, the impacts of various gradual reform measures[7] and technological policies on efficiency and productivity of the pre-reform period might be studied; this would provide more direct information on the success or failure of Ministry of Agriculture policies of that period.

3) If accurate price information on both farm inputs and outputs in the pre-reform period were available, the calculation of farm allocative efficiency may be useful in further testing on the success of government policy in saving costs and increasing farm efficiency.

4) Recent developments in stochastic DEA modelling may provide an opportunity to accommodate the noise in the data (Land *et al.*, 1993; Banker, 1996; Grosskopf, 1996; and Simar, 1996). This would possibly produce more reliable results. Alternatively, the DEA window analysis approach (Charnes, Clark, Cooper and Golany, 1985) could be used to test the stability of the efficiency scores across time.

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[7] For instance, comprehensive data on outputs and inputs of the crop farms which are engaged in new forms of incentive systems and those outside these incentive systems could enable one to conduct a comparative study of the direct impacts of these measures on farm performance.